08:42:22 OCA PAD INITIATION - PROJECT HEADER INFORMATION 02/23/88

Active

Project #: E-25-M36 Cost share #: Rev #: 0
Center # : R6454-0A0 Center shr #: OCA file #:
Work type : RES
Contract#: 19X-SB711C Mod #: Document : SUBCONT
Prime #: DE-AC05-84OR21400 Contract entity: GTRC

Subprojects ? : N
Main project #:

Project unit: ME Unit code: 02.010.126
Project director(s):
EICHHOLZ G G ME

Sponsor/division names: OAK RIDGE NAT'L LAB / MARTIN MARIETTA
Sponsor/division codes: 240 / 001

Award period: 880101 to 880930 (performance) 880930 (reports)

Sponsor amount	New this change	Total to date
Contract value	25,005.00	25,005.00
Funded	25,005.00	25,005.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: BIOASSAY ACTION LEVELS FOR SELECTED RADIONUCLIDES

PROJECT ADMINISTRATION DATA

OCA contact: John B. Schonk 894-4820

Sponsor technical contact

(000)000-0000

Sponsor issuing office

J.E. SCHULTZ
(615)576-1448
MARTIN MARIETTA ENERGY SYSTEMS
P.O. BOX M
OAK RIDGE, TN 37831

Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : DPAS supplemental sheet
Equipment title vests with: Sponsor X GIT

Administrative comments -
PROJECT INITIATION

2/88

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Date 5/1/89

roject No. E-25-M36 Center No. R6454-0A0

roject Director G. G. Eichholz School/Lab ME

ponsor Martin-Marietta Energy Systems Inc.

ontract/Grant No. 19X-SB711C GTRC XX GIT ___

rime Contract No. DE-AC05-840R21400

itle Bioassay Action Levels for Selected Radionuclides

ffective Completion Date 12/31/88 (Performance) 12/31/88 (Reports)

loseout Actions Required:

___ None
___ Final Invoice or Copy of Last Invoice
X Final Report of Inventions and/or Subcontracts - Patent questionnaire sent to P/
X Government Property Inventory & Related Certificate
___ Classified Material Certificate
X Release and Assignment
___ Other ___

ncludes Subproject No(s). ___

ubproject Under Main Project No. ___

ontinues Project No. ___ Continued by Project No. ___

istribution:

X Project Director
X Administrative Network
X Accounting
X Procurement/GTRI Supply Services
X Research Property Management
___ Research Security Services
X Reports Coordinator (OCA)
X GTRC
X Project File
2 Contract Support Division (OCA)
___ Other ___

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March 14, 1988

Please reply to:

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ATLANTA, GEORGIA 30332 U.S.A.

Dr. James S. Bogard
Environmental and Occupational Safety Div.
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37831

Monthly Progress Letter - Our Project E25-M36

Dear Dr. Bogard:

Owing to the late contractual start of the dosimetry project, there is not much to report at this stage. I spent a useful day at ORNL on March 7, 1988 discussing the project with Keith Eckerman, Mint Thein and yourself. As a result the project procedure was clarified and a series of nuclides was identified for priority in evaluation.

We have worked out our own approach in the meantime with primary reliance on ICRP 10 and 30 and the Lessard BNL report. I still look forward to receiving a copy of the Dunning report from you.

Please call me if you have any questions, at 404-894-3722.

Yours sincerely,

G. G. Eichholz
Regents' Professor

GGE/jr

P.S. We just received the contract on the TLD project and are launching right into it.

cc: P. Heitmuller (OCA)

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April 15, 1988

Please reply to:
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Dr. James S. Bogard
Environmental and Occupational Safety Div.
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37831

Monthly Progress Report - Our Project E25-M36

Dear Dr. Bogard:

During the month considerable progress has been made to develop a reasonable technical approach to the problem and to gain experience in utilizing the data bases in ICRP 10 and 30, the Lessard BNL report and the Dunning report. Applying both the exponential and the power series models to the case of cesium-137, reasonable agreement between the models was obtained, but it also became clear that their use during the first 24 hours after inhalation is subject to some limitations. There is also a discrepancy arising from the different mean particle sizes assumed in the various reports and we are trying to reconcile these calculations, adopting an AMAD of one micron as the "standard" size.

Work is under way on uranium and a method has been developed, based on the BNL data, to estimate lung retention and to calculate dose. We have spent some time defining the nature of our input data (measured excretion, leading to an inhalation estimate) and the required output in terms of lung dose, fraction of ALI and 50-year dose commitment.

It is planned for Mr. T. K. Haider to visit your group on April 22, 1988 for discussion. That will help him gain more of a perspective on the problem and, in discussion with you and Dr. Eckerman, may resolve some questions on alternative model approaches that may have arisen.

We are proposing to submit an abstract on this work to Dr. Swaja for the Orlando meeting in October 1988. At this stage, the abstract has to be worded rather vaguely and you might explain to him that we expect to have some solid results by the end of summer.

Please call me if you have any questions.

Yours truly,

G. G. Eichholz
Regents' Professor

GGEk

cc: P. Heitmuller (OCA)

Telephone: 404-894-3720 Telex: 542507 GTRIOCAATL Fax: 404-894-3120 (Verify: 404-894-6951)

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May 18, 1988

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ATLANTA, GEORGIA 30332 U.S.A.

Dr. James S. Bogard
Environmental and Occupational Safety Division
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tennessee 37831

Monthly Progress Report - Our Project E25-M36

Dear Dr. Bogard:

During the past month work has been concentrated on uranium dose estimation using the data base in ICRP10 and 30 and the Lessard BNL report. A literature search has been done on sources of uranium dust, solubility of uranium oxides in vitro and in vivo, the feasibility of determining lung dose from excretion rates, and regulatory guidelines. A draft outline of this review is attached as requested. In addition, we are looking at the available data bases for plutonium and neptunium, with particular reference to ICRP48.

Mr. T. K. Haider, the graduate student doing much of the work, visited ORNL on April 22 and gave an impromptu presentation of the present status and had discussions with several members of your group.

An abstract on the general approach to this problem has been submitted for the Orlando meeting in October, 1988.

Please call me at 404-894-3722 if you have any questions.

Yours truly,

G. G. Eichholz
Regents' Professor

GGE/bc
cc: P. Heitmuller (OCA)

Telephone: 404-894-3720 Telex: 542507 GTRIOCAATL Fax: 404-894-3120 (Verify: 404-894-6951)

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June 9, 1988

Dr. James S. Bogard
Environmental and Occupational Safety Division
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, Tennessee 37831

Monthly Progress Report - Our Project E25-M36

Dear Dr. Bogard:

Since our last report, dose calculations have been performed for plutonium inhalation. ICRP 30 and 79 models have been compared and its concluded that the ICRP 79 model, which is concerned with chronic exposure and does not consider excretion explicitly, is not really relevant to our concerns.

The ICRP 30 model seems to give a good estimate of intake from excretion fractions when corrected for particle size and elapsed time since the bolus intake(s).

Chi square statistics are used in estimating intake and the procedures for working back from excretion data are not greatly different for different models. A complete method for Pu, sample calculations and excretion data may be expected in early July.

I will be away in the meantime, but in case of questions, please contact Mr. T. K. Haider here.

Yours truly,

G. G. Eichholz
Regents' Professor

GGE/bc
cc: P. Heitmuller (OCA)
R.F. Dawkins (ME)

FILE Project file E25 M36

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July 15, 1988

Dr. James S. Bogard,
Environmental and Occupational Safety Division
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831

Monthly Progress Report - Our Project E25-M36

Dear Dr. Bogard,

During the past months, calculations have been done for U and Pu intake values as a function of particle size. Reasonably good agreement has been obtained with reported measurements on excretion following UF_6 inhalation. Uncertainties are relatively high and we are trying to quantify them.

Work is also under way to tabulate relationships between excretion values, at various times after intake, with calculated lung dose and fractional ALI, which I consider the primary objective of this project.

We would welcome an opportunity to discuss this work, if you are still planning a visit here.

Yours sincerely,

Geoffrey G. Eichholz
Regents Professor

cc: P. Heitmuller (OCA)
R. F. Dawkins (ME)

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August 17, 1988

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ATLANTA, GEORGIA 30332 U.S.A.

Dr. James S. Bogard
Division of Environmental & Health Protection
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831

Monthly Progress Report - Our Project E25-M36

Dear Dr. Bogard,

During the month relationships between excretion, intake, lung dose and ALI have been recalculated and tabulated for U-238 and Pu-239 particulates and it is planned to extend this procedure to other nuclides.

We expect to discuss progress on this project and the logical next stages with you and your colleagues during a visit to ORNL planned for Friday, August 19, 1988 and hope to discuss various aspects of this work in more detail then.

Yours sincerely,

Geoffrey G. Eichholz
Regent's Professor

GGE/lg

cc: P. Heitmuller (OCA)
R.F. Dawkins (ME)

Telephone: 404-894-3720 Telex: 542507 GTRIOCAATL Fax: 404-894-3120 (Verify: 404-894-6951)

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September 14, 1988

Dr. James S. Bogard
Division of Environmental & Health Protection
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831

Monthly Progress Report - Our Project E25-M36

Dear Dr. Bogard,

Since our last report, the dose calculations have been on a routine program with a standard format and data have now been tabulated for the actinides of interest.

Mr. Haider and I visited your group on August 19 and as a result the list of radionuclides to be covered has been updated.

We have requested a slight extension of the contract period to permit us to complete these calculations.

Sincerely,

Geoffrey G. Eichholz
Regents Professor

GGE/lg

cc: P. Heitmuller (OCA)
R.F. Dawkins (ME)

Telephone: 404-894-3720 Telex: 542507 GTRIOCAATL Fax: 404-894-3120 (Verify: 404-894-6951)

E-25-M36

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October 14, 1988

Dr. James S. Bogard
Div. of Environmental & Health Protection
Oak Ridge National Laboratories
P.O. Box 2008
Oak Ridge, Tennessee 37831

Monthly Progress Report - Our Project E25-M36

Dear Dr. Bogard:

During the past month the bulk of the proposed dose calculations have been done and data have been tabulated for U, Pu, Am, Sr, Ce and Cs, with Co being worked on at the moment. The remaining nuclides, H-3 and C-14 are less well documented and may require a different approach for different airborne compounds. Consequently, I am not sure that we will be able to complete work on those two within the term of the present contract.

I hope to put together the methodology and results of the present work by the middle of next month and will send you the draft report for your review.

In the meantime we will make a preliminary presentation of this work at the Orlando Dosimetry Conference in early November.

Please give me a call at 404-894-3722 if there are any questions.

Yours sincerely,

Geoffrey G. Eichholz
Regents' Professor

GGE/cv

cc: P. Heitmuller (OCA)
R. F. Dawkins (ME)

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October 14, 1988

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Dr. James S. Bogard
Div. of Environmental & Health Protection
Oak Ridge National Laboratories
P.O. Box 2008
Oak Ridge, Tennessee 37831

Monthly Progress Report - Our Project E25-M42

Dear Dr. Bogard:

The project now has entered essentially a routine phase. Both types of TLD badges are being exposed, as planned, over a range of dose rates and total doses. Three batches have been sent to ORNL for reading and we have just received the first list of readings from Dr. Rhea.

These activities will continue during the coming weeks.

Yours sincerely,

Geoffrey G. Eichholz
Regents' Professor

GGE/cv

cc: P. Heitmuller (OCA)
R. F. Dawkins (ME)

Telephone: 404-894-3720 Telex: 542507 GTRIOCAATL Fax: 404-894-3120 (Verify: 404-894-6951)

BIOASSAY ACTION LEVELS FOR SELECTED RADIONUCLIDES

G. G. Eichholz and T. K. Haider

Final Report

Contract No. 19X-SB7111C - Georgia Tech Project E25-M36

Submitted to the
Division of Environmental and Health Protection
Oak Ridge National Laboratory
Oak Ridge, TN 37831

Prepared by
Nuclear Engineering and Health Physics Program
Georgia Institute of Technology
Atlanta, GA 30332

November 1988

BIOASSAY ACTION LEVELS FOR SELECTED RADIONUCLIDES

G. G. Eichholz and T. K. Haider

Final Report

Contract No. 19X-SB7111C - Georgia Tech Project E25-M36

Submitted to the
Division of Environmental and Health Protection
Oak Ridge National Laboratory
Oak Ridge, TN 37831

Prepared by
Nuclear Engineering and Health Physics Program
Georgia Institute of Technology
Atlanta, GA 30332

November 1988

SUMMARY

A practical problem in internal dosimetry may arise when an individual is accidentally exposed to airborne radioactive materials. Normal procedure would call for urine analysis to establish the presence of any body burden and to permit an assessment of the radiological consequences of this event.

Current assessment procedures, based on ICRP 30 methodology, are largely directed to steady-state chronic exposures. This report presents data obtained on the basis of the ICRP 30 model for the lung doses resulting from singular inhalation events as deduced from measurements on excreta. Tables are presented for the fraction of the annual limit of intake (ALI) represented by unit activity in the excreta as a function of sampling time and the concomitant dose commitments.

Data have been tabulated, for the various lung retention classes, for Co-60; Sr-89, 90; I-125, 131; Cs-134, 137; U-233, 234, 235, 238; Pu-238, 239 and Am-241, 242.

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INTRODUCTION

The accurate estimate of internal dose and implied dose commitment for a person, who has been occupationally or accidentally exposed to airborne activity, is an important aspect of the safe operation of any nuclear facility that has a potential for such exposures. In the past, such internal doses were calculated on the basis of the critical organ dose postulated in the procedure outlined in ICRP Report No. 2 (1), which simply divided source material according to whether it was soluble or insoluble. The redefinition of internal dose through a distinction between stochastic and non-stochastic consequence chains and the use of an improved lung model were incorporated in the more recent recommendations published as ICRP Reports 26 (2) and 30 (3). The emphasis in the latter is on the relationship between intake and committed tissue dose-equivalent by means of a series of general transfer equations, that are interlinked and require a detailed knowledge of all relevant transfer coefficients. This is not, typically, a calculation that can be done at short notice.

The present report deals with the situation where a worker may be exposed to unknown concentrations of airborne materials for a short time and a determination must be made of the effective dose equivalent received and the fraction of the annual limit of intake (ALI) the particular event represented. Although the particular radionuclides and their physical/chemical form will be known, in general, the only quantitative information available will be the activity excreted. Hence, the purpose of

the present work was to provide a direct link between the activity in excreta, essentially in urine, at specific sampling times after intake and the calculated lung dose. Figure 1 illustrates the relationships involved, i.e. given a urinalysis assay, the presumed intake is estimated and from this the lung dose, fractional ALI committed and dose commitment are derived.

Fortunately, it was not necessary to go back to first principles. Retention models have been published in ICRP 10(4) and ICRP 30 (3). A very substantial tabulation of organ deposition and excretion coefficients for most radionuclides of interest has been published by Lessard et al. (5) and Dunning (6) has tabulated organ doses from inhalation for particle sizes of 0.3, 1.0 and 5 μm AMAD for environmentally significant radionuclides, as well as the 50-year dose commitment per microcurie intake. The present task then was to correlate this information and to present it in a readily usable form. The principal interest lay in the evaluation of actinide radionuclides, which have been considered in more detail, and of some of the major, non-gaseous, fission products. A typical discussion of uranium product inhalation was published recently by Kvasnicka (7); a parallel discussion of intake retention functions and the estimation of internal radiation doses by Skrable et al. (17) appeared while this report was in preparation.

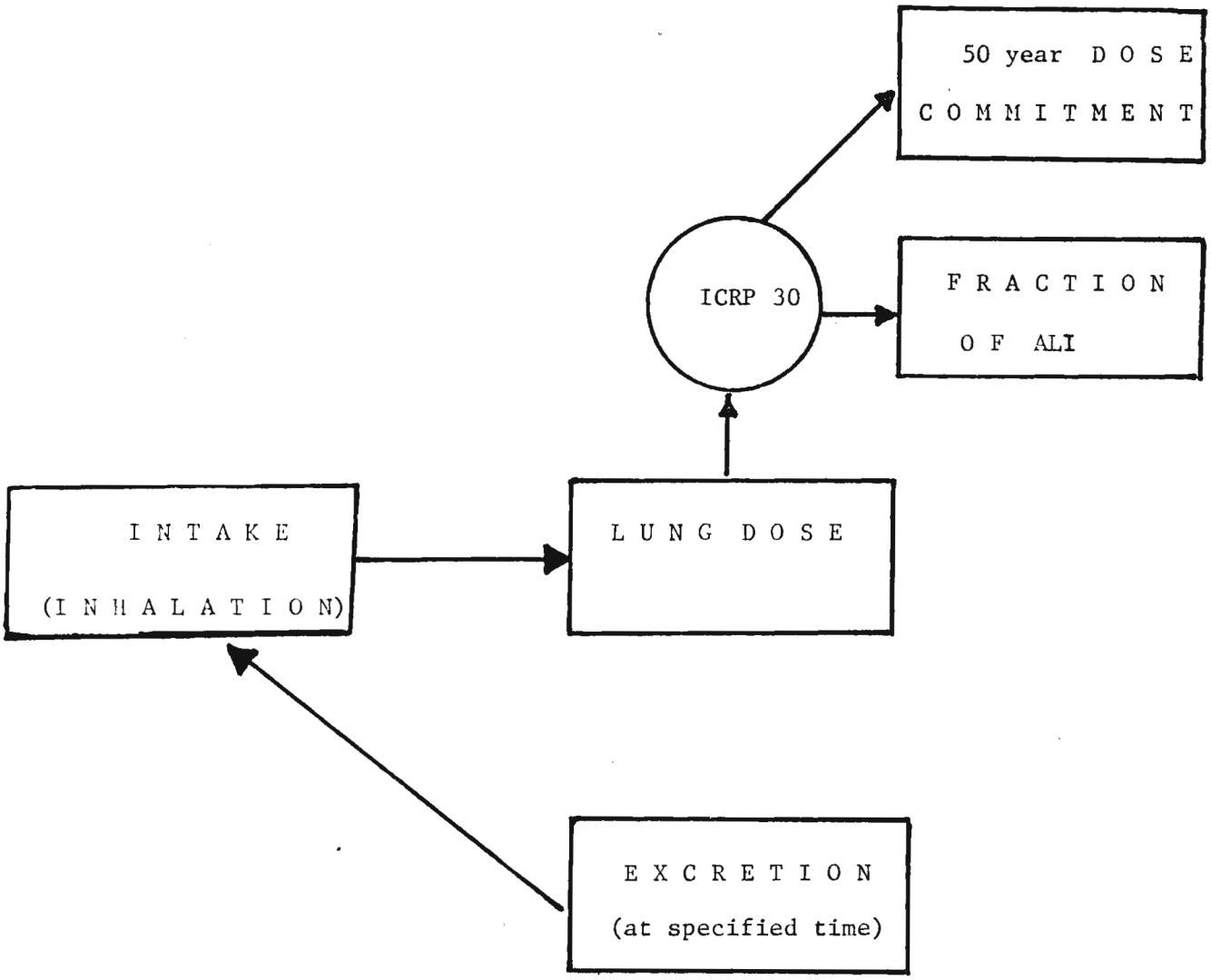

Figure 1: Schematic Relationship Between Intake, Excretion and Dose

CHOICES OF A MODEL

To obtain a satisfactory correlation between uptake, excretion and lung dose for inhaled particulates the choice of an appropriate model is important. This entails the construction of a compartmentalized structure with identifiable transfer paths between all organs of interest and between compartments within an organ, such as the lung, and the subsequent calculation of organ doses resulting from deposition in the critical organ; in the present case, this was the lung for most of the radionuclides considered. Most of the dose calculations are derived from refinements of the MIRD model (8), which led to calculations of absorbed fractions (of the dose) in various organs for a uniform deposition of active material in the lung. The relationship between deposition of inhaled material in the various regions of the lung, translocation into the blood stream and excretion through the kidneys is rather complex and depends on solubility, particle size, chemical form and partial diversion into the lymphatic system (9). The process of dissolution and translocation of actinide particles in lung fluids is difficult to analyze. Cooke and Holt (10) have attempted to simulate translocation in lung fluid for some uranium compounds and Ryan (11) for plutonium.

Figure 2 shows the respiratory model adopted in ICRP 30 (3), with a table for the removal half-times from the lung and the compartmental fractions for removal paths for each of the compartments. In general, removal to the lymph system is significant only for the pulmonary parenchyma (P) region. The fraction deposited in each region on

Region	Compartment	Class D T day	D F	W T day	W F	Y T day	Y F
N–P	a	0.01	0.5	0.01	0.1	0.01	0.01
($D_{N-P} = 0.30$)	b	0.01	0.5	0.40	0.9	0.40	0.99
T–B	c	0.01	0.95	0.01	0.5	0.01	0.01
($D_{T-B} = 0.08$)	d	0.2	0.05	0.2	0.5	0.2	0.99
	e	0.5	0.8	50	0.15	500	0.05
P	f	n.a.	n.a.	1.0	0.4	1.0	0.4
($D_P = 0.25$)	g	n.a.	n.a.	50	0.4	500	0.4
	h	0.5	0.2	50	0.05	500	0.15
L	i	0.5	1.0	50	1.0	1 000	0.9
	j	n.a.	n.a.	n.a.	n.a.	∞	0.1

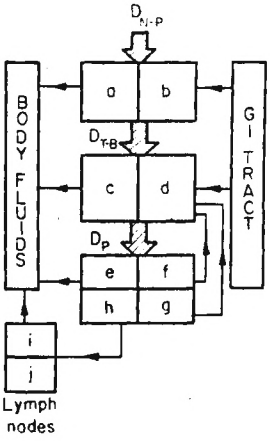

Figure 2: Mathematical model and clearance times for the respiratory system (3)

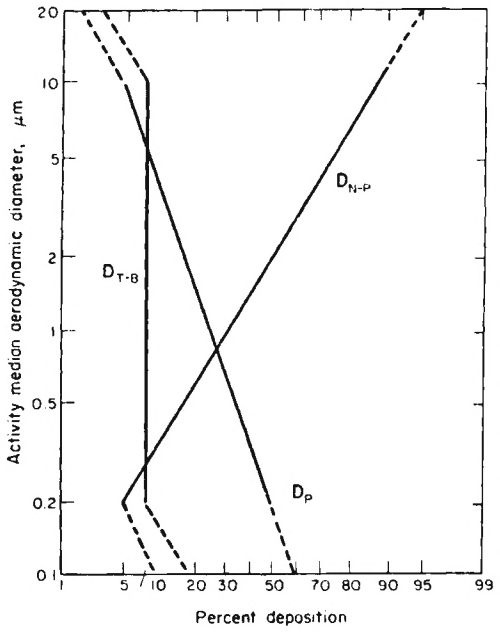

Figure 3: Dust deposition in lung compartments for various particle sizes (3)

inhalation depends on particle size, as expressed by the activity median aerodynamic diameter (AMAD), as shown in Fig. 3 (3). The lung retention is a function of particle size and chemical solubility and is roughly categorized by the Classes D, W and Y, which are assigned largely on an empirical basis (e.g. 12).

The lung model gives rise to a series of interlinked first-order differential equations describing the transport from one compartment, in Fig. 2, to another in terms of coefficients describing the inhalation rate, the biological clearance rates of each compartment, and the radioactive decay rates for the radionuclide. The various models proposed are similar in format, but differ in their completeness and in the approximations attempted. This is illustrated in Table 1, which compares several equations proposed in ICRP 10 (4) and 10A (draft) to describe the retention in man of strontium-90. Note that most equations are composed of exponential terms, but Case c includes a power term. Since the integrated retention determines the committed dose, it is obvious that the choice of equation (or model) is important.

A similar situation exists for excretion models. Again several pathways have to be considered and Table 2 shows the fractional excretion equations proposed in ICRP 10 (4).

The following pages illustrate the consequences of choosing one or the other model for the case of strontium-90/89, to indicate the magnitude of the difference in estimated doses that may arise.

TABLE 1

Proposed Retention Equations for ^{90}Sr (4)

ICRP 10 proposes several equations to describe retention in man.

R(t) = fraction of intake retained in total body t days after the contamination event

Q = time integral of internal contamination resulting from an uptake or deposition of 1 μCi expressed in μCi-days

t = # of days after contamination

a. $$R(t) = 0.4 \exp\left[-\frac{0.693}{1.7}t\right] + 0.3 \exp\left[-\frac{0.693}{4.4}t\right] + 0.14 \exp\left[-\frac{0.693}{50}t\right] + 0.15$$

b. $$R(t) = 0.73 \exp\left[-\frac{0.693}{3}t\right] + 0.1 \exp\left[-\frac{0.693}{44}t\right] + 0.17 \exp\left[-\frac{0.693}{4000}t\right]$$

c. $$R(t) = 0.5 \exp\left[-\frac{0.693}{2.4}t\right] + 0.5\, t^{-0.2}$$

d. $$R(t) = 0.56 \exp\left[-\frac{0.693}{1.8}t\right] + 0.24 \exp\left[-\frac{0.693}{8}t\right] + 0.2 \exp\left[-\frac{0.693}{600}t\right]$$

TABLE 2

Fractional Excretion Equations (4)

$Y_u(t)$ = fraction excreted by single routes
$Y(t)$ = fraction excreted by all routes per day on the t th day after contamination event

a. $$Y(t) = 0.73 \left[\frac{0.693}{3}\right] \exp\left[-\frac{0.693}{3} t\right] + 0.1 \left[\frac{0.693}{44}\right] + 0.17 \left[\frac{0.693}{4000}\right] \exp\left[\frac{-0.693}{4000} t\right]$$

b. $$Y_u(t) = -0.8 \frac{dR}{dt} = 0.12 \exp\left[-\frac{0.693}{2.4} t\right] + 0.08\, t^{-1.2}$$

c. $$Y_u(t) = -0.67 \frac{dR}{dt} = 0.14 \exp\left[\frac{-0.693}{1.8} t\right] + 0.14 \exp\left[\frac{0.693}{8} t\right] + 1.5 \times 10^{-4} \exp\left[-\frac{0.693}{600} t\right]$$

COMPARISON OF MODELS - ^{90}Sr CASE

A. Dose calculation for a given uptake

The first problem in estimating the 50-year radiation dose resulting from a single intake of strontium is to select a retention equation. Of the four equations, b and c were derived from a survey of literature and proposed for use in radiation protection work. Sample calculations of ORNL (13) used Equation b. Equation b is an exponential model and easily integrable. Equation c is a power function and an exponential function.

We evaluate ^{90}Sr first.

$$Q' = \left\{ \int_0^T 0.73 \exp\left[-\left(\frac{\ln 2}{3} + \frac{\ln 2}{T_r} \right) t \right] tdt + \int_0^T 0.10 \exp\left(-\frac{\ln 2}{44} - \frac{\ln 2}{T_r} \right) tdt + \int_0^T 0.17 \exp\left(-\frac{\ln 2}{4000} - \frac{\ln 2}{T_r} \right) tdt \right\} q_o$$

where T_r = radioactive half-life in days.

q_o = initial uptake in μCi

Q = internal deposition as defined in Table 1

$Q' = q_o Q$ for an uptake of q_o

For ^{90}Sr 50 year dose - $T_{1/2}$ = 10,000 days

$$Q = 0.73 \int_0^{50\ yr} 0.73 \exp\left(- \frac{\ln 2}{3} - \frac{\ln 2}{10{,}000} \right) t\ dt$$

$$+ \int_0^{50\ yr} 0.10 \exp\left(- \frac{\ln 2}{44} - \frac{\ln 2}{10{,}000} \right) t\ dt$$

$$+ \int_0^{50\ yr} 0.17 \exp\left(- \frac{\ln 2}{4{,}000} - \frac{\ln 2}{10{,}000} \right) t\ dt$$

$$Q = \left[(0.73) \frac{1}{0.231} e^{-0.231\ t} + 0.1 \frac{1}{0.01575} e^{-0.01575t} + \frac{0.17}{0.0002426} e^{-0.0002426t} \right] \Bigg|_0^t$$

$t = 50\ yr = 18{,}250\ days$

$Q = 3.16 + 6.349 + 700.74\ (1 - 0.0119) = 3.16 + 6.349 + 692$

$= 701.91 \sim 702\ \mu Ci\text{-day}.$

NOTE: ICRP 10 gives a value of 709 μCi-day.

The discrepancy arises from two causes:

1. They used bone as the critical organ and did not include the first term in equation b, because it does not describe the retention in bone.

2. They ignored the upper limits. The upper limit is zero for the first two terms and 0.0119 for the third term.

If the dose to the bone only is of interest, one obtains (first term ignored) 6.349 + 692 = 698.349, as opposed to 709 μCi-day in ICRP 10.

According to ICRP 10, use of the power function yields a value for Q of 980 μCi-days. The difference between the two models then is:

$$\left| \frac{702 - 980}{702} \right| \times 100\% = 39.6\%$$

if 702 is taken to be the reference value; otherwise if 980 is taken to be the reference value, the percent different is 28.36%. Either way, there is a significant difference.

ICRP 10 (4) has tabulated the values of Q using power functions and exponential functions also for ^{89}Sr:

Q using power function	=	18.1 for Bone	difference = 4.4%
Q using exponential function	=	18.9 for Bone	

It is noted that for short-half-life nuclides, both power function and exponential function give about the same value for Q. However, the power function gives a much larger value for Q in the case of long-lived radionuclides, such as ^{90}Sr. ^{89}Sr has a 50.6 day half life.

In order to be conservative, ICRP 10 uses the power function to calculate dose to the critical organ.

A. Dose Calculations

Dose to the total body from an intake of 1 μCi is given by (4)

$$D = Q \times 51.2 \times \frac{\epsilon}{m} \text{ in rems}$$

where m is the mass of the organ or total body weight and

$$\epsilon = \sum \text{EF (RBE) n (E in MeV) for the appropriate organ}$$

For Bone m = 7000 g

$$\epsilon = 5.5,$$

and we obtain

$$D = 51.2 \times 698.349 \times \frac{5.5}{7000} = 28.10 \text{ rem}$$

ICRP CALCULATION

$$D = 51.2 \times 709 \times \frac{5.5}{7000} = 28.522 \text{ rem}$$

Use of the power function turns out to be slightly more conservative. In that case the calculation gives

D = 39.4 rem, for a difference in dose to the bone of 27.6%.

It is obviously important to be consistent in using these models, but equally important not to overestimate dose merely for conservatism.

Calculation of First-Year Dose To the Bone

For ^{90}Sr

Exponential Model-:

$$Q' \text{ (1 year)} = q_o [3.16 + 6.35 \ (1 - 0.003) + 700 \ (1 - 0.915)]$$

integrating 0 - 1 year = 68.99 = 68.99 ~ 69 q_o μCi-day

∴ The first year dose to the whole body

= 69 q_o x 0.04 rem/μCi-day = 2.76 q_o rem

Dose to bone (power function)

$$Q' = q_0\ 0.5 \int_0^{1\ year} \exp\left(- \frac{\ln 2}{T_r} t \right) t^{-0.2}\ dt\ (\mu Ci\text{-days})$$

Dose to bone (exponential model)

$$Q' = q_0\ [(6.35\ (1 - 0.003) + 700\ (1 - 0.915)]$$

$$= 65.8\ q_0\ \mu Ci\text{-day}$$

$$\text{Dose} = 65.8\ q_0 \times 0.04 = 2.63\ q_0\ \text{rem}$$

Proportional dose to bone = $\frac{2.63}{2.76}$ x 100% = 95.3% of whole body dose

Since over 95% of the dose is to the bone, the dose to the whole body, using the power function, is not considered in detail.

<u>^{89}Sr (exponential model) whole body</u>

$$Q = 0.73 \int_0^{365 \times 50} \left[\exp\left(- \frac{\ln 2}{3} - \frac{\ln 2}{51} \right) t + \exp\left(- \frac{\ln 2}{44} - \frac{\ln 2}{51} \right) t + \exp\left(- \frac{\ln 2}{4000} - \frac{\ln 2}{51} \right) t \right] dt$$

= 2.98 + 3.41 + 12.51 = 18.90 μCi-days

For Q (1 yr) = 2.98 + 3.41 + 12.51 (1-0.0007) = 18.81 μCi-days

For Bone only ignore first term (ICRP 10, p.56)

Then Q = 15.92 μCi-days

Q (1 yr) = 15.83 μCi-days

and f (dose determination function) = $\frac{\text{Dose}}{Q}$

Dose Commitment

Bone $D_{50} = 51.2 \times 15.92 \times \frac{2.8}{7000} = 0.326 \simeq 0.33$ rem

Whole Body $D_{50} = 51.2 \times 18.9 \times \frac{28}{7000} = 0.387 \simeq 0.39$ rem

f (whole body) = $\frac{0.39}{18.9} = 0.0206 \frac{\text{rem}}{\mu\text{Ci-day}}$

Q (1 year) = 18.81 μCi-day per microcurie intake

Dose to 1st year = 18.81 x 0.0206 = 0.387 rem to whole body per μCi intake

Dose to bone = $15.83 \times \frac{0.33}{15.92} = 0.328$ rem*

First Quarter Bone Dose Per μCi-Intake

Q (90 day) = 2.98 + (1-0.071) 3.41 + 12.51 (1-0.2897)

Whole Body = 2.98 + 3.168 + 8.885

= 15.04 μCi-days

Bone = 12.05 μCi-days

Dose D_{90} (Whole Body) = $\frac{0.39}{18.9} \times 15.04 = 0.31$ rem

Dose (Bone) = $\frac{0.33}{15.92} \times 12.05 = 0.25$ rem

*NOTE: ICRP 10 makes a mistake in calculating the dose to the bone. They calculated the whole body dose, but refer to it as bone dose.

B. Uptake Calculations From Excretion Data

Evaluation of Uptake: The initial uptake q_o may be determined by the excretion curves in ICRP 10A.

Using the Power function model: (ICRP 10A)

excretion at Day 1 = 21.1%

excretion at Day 2 = 12.5%

excretion at Day 7 = 2.9%

excretion at Day 365 = 0.0084%

$$\therefore \text{Amt. of intake } q_o = \frac{A}{\%\ \text{excretion}} ,$$

where A = Amt. of activity found in the Bioassay.

For ^{90}Sr:

$$\therefore \text{The 50 year dose to the bone will be} = \frac{A}{\%\ \text{excretion}} \times 39.4 \text{ rem}$$

The whole-body dose is approximately 5% more.

Exponential Model

$$D_{50} = \frac{A}{\%\ \text{excretion}} \times 28.1 \text{ rem}$$ (from p. 12)

$$\text{First year dose} = \frac{A}{\%\ \text{excretion}} \times 2.63\ q_o \text{ rem}$$

To correlate intake and excretion, an excretion coefficient is defined as

f_u = fraction of uptake excreted in urine

For any uranium, f_u = 85%, if u refers to amount found in urine

f_F = 15%, referring to fecal excretion

In reviewing radioisotopes of the same element, the excretion coefficients will be the same, as long as materials in the same lung class are compared. Excretion coefficients have been tabulated by Lessard et al. (5), either as such or in terms of an inverse quality, the Intake Retention Function (IRF).

CALCULATION OF ALI AND D_{50}

The above comparison showed that there was no particular benefit in using a power function relationship, except at very small values of t, and it was decided to adopt the exponential ICRP 30 model for all cases considered.

A two-stage calculation was performed:

a) calculation of intake values for each nuclide for a given excretion (urinary) activity; and

b) calculation of fractional ALI and critical organ dose for that intake value, all normalized to unit activity in the urine sample.

Table 3 gives an example of the data base available for excretion data (5) and Tables 4 and 5 present examples for the data base for intake retention function, ALI and committed dose equivalent for the various lung classes (4, 5), as well as Derived Investigation Levels (DIL).

These data were used to calculate lung doses for single intake events which are tabulated in Tables 8 - 36.

TABLE 3
Example of Excretion Data (5)

ELEMENT DATA SHEET

ELEMENT: Uranium

PARTICLE SIZE: 1.0E+00 Microns

LUNG DEPOSITION:

Nasal Passages	Trachea and Bronchial Tree	Pulmonary Parenchyma
3.10E-01	8.00E-02	2.49E-01

SYSTEMIC RETENTION:

Coefficient	Rate Constant 1/Days
2.00E-01	3.47E-02
2.30E-02	1.39E-04
2.40E-01	1.16E-01
1.04E-03	4.62E-04
5.36E-01	2.27E+00

FRACTION FROM GI TRACT TO BLOOD (f_1): 5.00E-02 Ingestion

5.00E-02 Class D 5.00E-02 Class W 2.00E-03 Class Y

FRACTION OF SYSTEMIC UPTAKE EXCRETED THROUGH URINE (f_u): 1.0E+00

THE COMMON ISOTOPES OF URANIUM:

Mass Number	Half-life, Days
230	2.08E+01
231	4.20E+00
232	2.63E+04
233	5.79E+07
234	8.92E+07
235	2.57E+11
236	8.55E+09
237	6.75E+00

TABLE 4
EXAMPLE OF DATA BASE FOR D50 AND ALI (4) NEPTUNIUM

Committed Dose Equivalent in Target Organs or Tissues
Per Intake of Unit Activity (Sv/Bq) of Np-237)

ORAL	INHALATION
	CLASS W
f_1 = 1.E-02	f_1 = 1.E-02
GONADS	GONADS
2.5E-06	3.1E-05
R. MARROW	R. MARROW
1.5E-05	1.9E-04
BONE SURF.	BONE SURF.
1.9E-04	2.4E-03
LIVER	LIVER
4.1E-05	5.1E-04

Weighted Committed Dose Equivalent in Target Organs or Tissues
Per Intake of Unit Activity (Sv/Bq) of Np-237

ORAL	INHALATION
	CLASS W
f_1 = 1.E-02	f_1 = 1.E-02
GONADS	GONADS
6.1E-07	7.7E-06
R. MARROW	R. MARROW
1.8E-06	2.3E-05
BONE SURF.	BONE SURF.
5.7E-06	7.2E-05
LIVER	LIVER
2.5E-06	3.1E-05

Annual Limits On Intake, ALI, And Derived Air
Concentrations, DAC, (40 hr/wk) For Np-237)

ALI (Bq)		DAC (Bq/m^3)
ORAL	INHALATION	INHALATION
	CLASS W	CLASS W
f_1 = 1.E-02	f_1 = 1.E-02	f_1 = 1.E-02
3.E 03	2.E 02	9.E-02
(5.E 03)	(4.E 02)	
BONE SURF.	BONE SURF.	

Table 5

Example of Data Base for Intake Retention Function (IRF) (5)

Table 5.3.1 continued

Time Post Intake, days	IRF In Compartment			DIL In Compartment, Bq		
	Lungs	Total Body	24-Hour Urine	Lungs	Total Body	24-Hour Urine
U-238, Class W Inhalation, ALI = 2.52E+04 Bq						
1.0	2.11E-01	5.57E-01	4.13E-02	4.37E+00	1.15E+01	8.55E-01
5.0	1.45E-01	2.03E-01	2.69E-03	1.50E+01	2.10E+01	2.79E-01
10.0	1.32E-01	1.59E-01	1.75E-03	2.73E+01	3.29E+01	3.62E-01
30.0	1.02E-01	1.17E-01	7.28E-04	6.34E+01	7.27E+01	4.52E-01
100.0	4.18E-02	4.81E-02	2.43E-04	8.66E+01	9.96E+01	5.03E-01
200.0	1.15E-02	1.57E-02	7.49E-05	4.76E+01	6.50E+01	3.10E-01
365.0	1.66E-03	5.14E-03	1.29E-05	1.25E+01	3.89E+01	9.75E-02
U-238, Class Y Inhalation, ALI = 1.51E+03 Bq						
1.0	2.13E-01	5.85E-01	2.23E-03	2.64E-01	7.26E-01	2.77E-03
5.0	1.53E-01	1.83E-01	1.31E-04	9.49E-01	1.14E+00	8.13E-04
10.0	1.48E-01	1.50E-01	8.42E-05	1.84E+00	1.86E+00	1.04E-03
30.0	1.45E-01	1.46E-01	3.27E-05	5.40E+00	5.43E+00	1.22E-03
100.0	1.35E-01	1.35E-01	1.87E-05	1.68E+01	1.68E+01	2.32E-03
200.0	1.22E-01	1.22E-01	1.81E-05	3.02E+01	3.03E+01	4.49E-03
365.0	1.03E-01	1.04E-01	1.82E-05	4.67E+01	4.71E+01	8.26E-03
U-238, Ingestion, ALI = 7.33E+06 Bq						
1.0		7.01E-01	2.76E-01		4.22E+03	1.66E+03
5.0		3.37E-02	2.89E-02		1.02E+03	8.71E+02
10.0		1.23E-02	2.00E-04		7.41E+02	1.20E+01
30.0		5.14E-03	0.00		9.29E+02	0.00
100.0		1.50E-03	-		9.04E+02	-
200.0		1.18E-03	-		1.42E+03	-
365.0		1.14E-03	-		2.51E+03	-
Pu-239, Class W Inhalation, ALI = 2.03E+02 Bq						
1.0	2.11E-01	5.96E-01	2.83E-04	3.52E-02	9.94E-02	4.72E-05
5.0	1.45E-01	2.45E-01	5.39E-05	1.21E-01	2.04E-01	4.50E-05
10.0	1.32E-01	2.09E-01	2.54E-05	2.20E-01	3.49E-01	4.24E-05
30.0	1.02E-01	1.86E-01	1.76E-05	5.11E-01	9.31E-01	8.81E-05
100.0	4.18E-02	1.42E-01	1.12E-05	6.97E-01	2.37E+00	1.87E-04
200.0	1.15E-02	1.21E-01	7.89E-06	3.84E-01	4.04E+00	2.63E-04
365.0	1.66E-03	1.14E-01	4.96E-06	1.01E-01	6.94E+00	3.02E-04

EXPLANATION OF THE TABLES

One of the first practical problems is to define the nature of the excretion sample. In practical cases of unanticipated inhalation events, it is usually desirable to obtain a bioassay sample within 24 hours and this may be followed up by other samples over a longer period of time. Since the lung class indicates the typical time period of lung clearance to the kidney, the first 48 hours are of greatest interest for Class D material; longer sampling times may be appropriate for the other classes. Because the first sample usually would represent cumulative appearance of excreta in the bladder up to the time of voiding, Column 2 in the tables (Tables 9 - 36) represents the cumulative fraction available for excretion at that time (5). These figures incorporate any correction for radioactive decay and as long as one can assume that samples are assayed shortly after collection, no further decay correction will be needed. If more than one sample is obtained during the first 24 hours, these samples must use the difference in excretion fractions. After the first day, tabulated excretion fractions, as shown in Column 3, refer to the total activity obtained over any 24-hour period only, preceding time T. Using this information, Column 4 inverts those data to list the intake quantity, in becquerels (Bq), per unit activity (Bq) measured in the urine. Taking the published ALI data, Column 5 presents the fraction of ALI incurred per unit of urine activity measured at that time T. The sixth column lists the committed dose equivalent to the target organ, in sieverts (Sv) per becquerel detected in the urine sample, using the conversion factors for committed dose equivalent in the ICRP 30 Supplements. The

Weighted Committed Dose Equivalent per Bq detected is given in Column 7, again using data from ICRP 30 Supplements.

Inspection of the tables shows an initial decrease in the fraction of ALI incurred for a given amount of activity found in the urine. After a time commensurate with the clearance half life, that fraction increases rapidly, because for that activity still to be excreted after a longer period than the clearance half life, correspondingly larger amounts must have been deposited in the body and, consequently, higher lung doses have been incurred. This is illustrated in Figure 4 for the case of Class D Iodine-131.

USE OF THE TABLES IN APPENDIX A

To use these tables, one needs to measure the urine activity and note the collection ending time. For example, three days after intake a 24 hour urine sample has an activity of 1000 Bq. To find the intake, one would simply multiply the 4th column by 1000 to estimate the intake. To know what fraction of ALI that would represent, multiply the 5th column by 1000, and so on. It is necessary to know the lung class of the particlates to select the correct table.

One may estimate the dose from just one measurement, but it is recommended to make several equally spaced measurements, as there may be some short-term changes in metabolic conditions. This may affect some data points; therefore CHI-square statistics of the intake value is recommended.

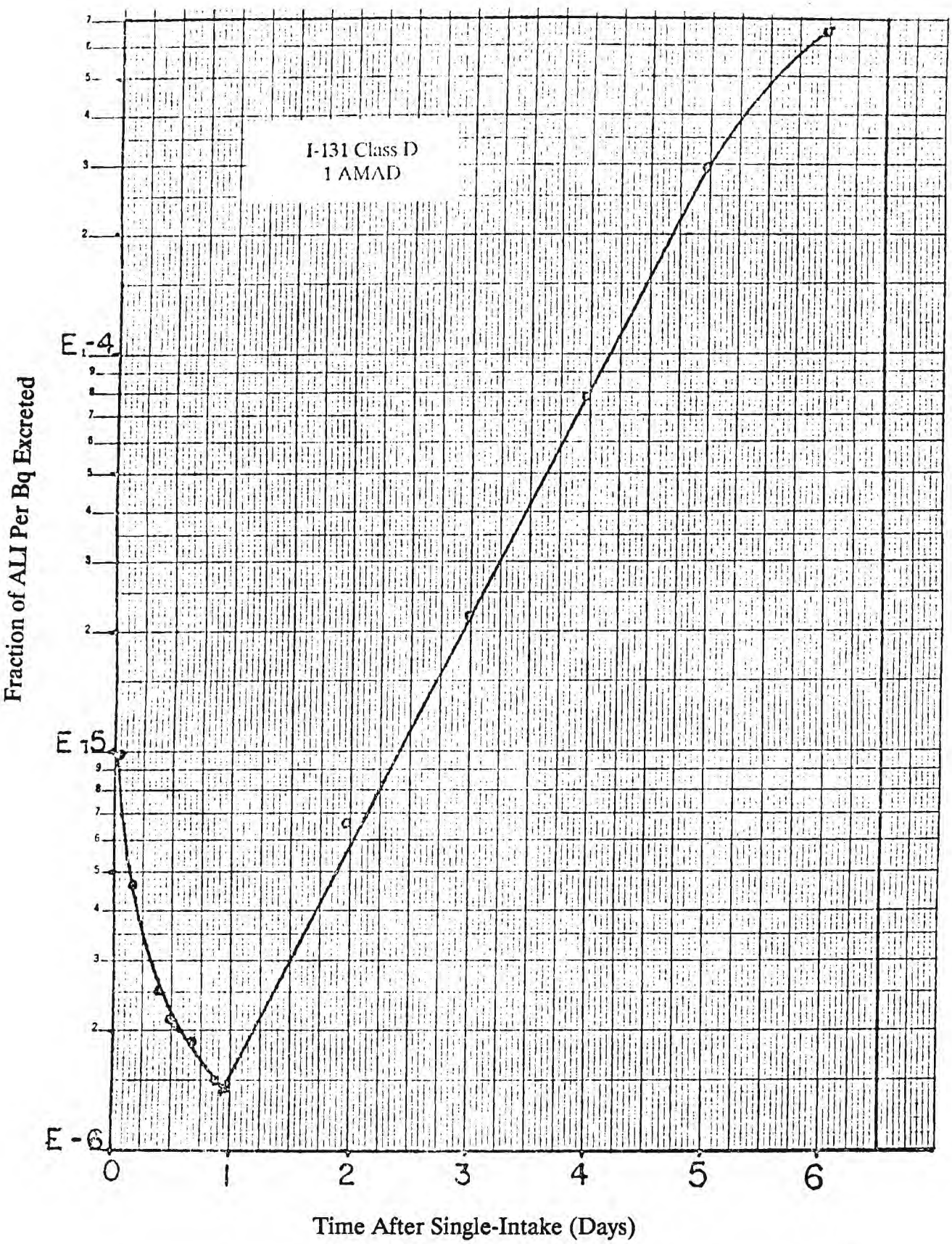

Figure 4: Fraction of ALI per Bq Excreted vs. Sample Time for I-131

When a urine sample is taken, it is important to know the collection time. It is also necessary to collect all of the urine excreted in the 24- hour sample. If some urine is lost, then an estimate is needed to normalize the sample into a 24-hour sample. Suppose, a person has excreted four times a day, but only the first and third samples are available. Roughly, this would represent half of the urine sample of the 24-hour urine sample. The total activity of the urine should be multiplied by two to normalize the sample to a 24-hour effective sample. To improve accuracy, additional samples should then be obtained. If the urine sample is not counted immediately after collection, a decay correction may be necessary as the tabulated collection time T is assumed to be close to the counting time. It should be noted that the decay of the parent may lead to an activity of a daughter. Thus, if the time of waiting to be counted is long, further decay corrections and ingrowth may have to be considered.

It may become necessary to make corrections for particle size, if it is other than 1 μm AMAD. ICRP 30 and NUREG/CR-4884 (5) provide a procedure to correct that. As discussed below, it should be noted that these tables give estimates for a single intake only. If there were multiple intakes or continuous intake, NUREG/CR 4884 (5) also provides a way to correct for that.

Sometimes it may be necessary to interpolate, especially for Class Y radionuclides. It is recommended to use exponential regression. The excretion values may be fitted to an exponential curve

$$y = a \exp(bt)$$

where

t = time after intake in days
y = fraction of intake appearing in urine in time t

a and b are constants determined from exponential regression. It is also recommended to check R_p, the regression coefficient. If R_p is 1±0.80 or above, then the data points have high correlation.

Example:

A 24 hour excretion value of Co-60, Class Y at t = 1 day is 4.65 E-03. Suppose it is desired to know the excretion value at t = 2 days. Excretion values for t = 3 days and t = 4 days are 2.4 E-03 and 1.28 E-03, respectively.

The data points are (1, ln 4.65 E-03), (3, ln 2.4 E-03) and (4, ln 1.28 E-03).

The R_p for this set of data is -0.9846 indicating high correlation among the data points. The equation is

$$y = 0.007354 \exp - (0.4158t)$$

at t = 2 days, $y = 0.007354 \exp - (0.4158 \times 2) = 3.20$ E-03

i.e. the 3rd column gives 3.20 E-03 at t = 2 days.

Best Estimate of Intake

Values for best estimate of intake were based on the minimum value of chi-squared, χ^2, which is defined as the ratio of the sum of the squares of the differences between measured values, A(i), and the expectation values, (R_iI), and the variance, $V_i^2 \sim 2.80$,

$\chi^2 = A(i) - (R_iI)^2/V_i^2$ and $d\chi^2/dI = 0$.

For constant variance

$$I = \frac{\Sigma_{(i)} R_{(1)} A_i}{\Sigma R^2_{(i)}}$$

Where

I	=	best estimate of intake (μg or Bq),
A (i)	=	sample measurement (μg or Bq),
R (i)	=	fraction of intake in accumulated urine at time of ith sampling. (Given in Ref. 5).
Δt (i)	=	$t_{(i)} - t_{(i-1)}$
A (i)	=	$c(i) \times 1.4$ L/d $t_{(i)}$
A (i)	=	$\Delta A(1) + \Delta A(2) + \ldots . \Delta A(i)$

where

i	=	sequence no. of sample,
$t_{(i)}$	=	time post intake for ith sampling (days),
C(i)	=	concentration of element, e.g. uranium in urine from ith sampling (μg/liter),
$\Delta A(i)$	=	uranium in ith sample of urine (μg)
A(i)	=	uranium in accumulated urine up to time = t(i)

By inspection, it is evident that the earlier data are weighed more heavily. The reason behind that is that a significant percentage of the activity is excreted in the first few days and is statistically more reliable.

It may be noted that where there is only one sample available, the equation reduces to a simple form.

For one sample $\underline{i = 1}$,

$$I = \frac{\Sigma_i R_i A_i}{\Sigma_i R_i^2} = \frac{R_1 A_1}{R_1^2} = A_1 \frac{1}{R_1}$$

The term $1/R_1$ appears in the tables in Column 5 and again A_1 is the activity of the sample.

The alternative method described above becomes an increasingly better estimate of the intake as the number of samples get larger. Since it is weighted, a short-term change in metabolic activity does not affect the value of the intake. Short-term changes may give rise to a very large error.

A less complicated method than the alternative method above is to evaluate the intake by using the Tables in Appendix A provided and then take the mean of all intakes. A comparison of both methods shows that they give similar results. Once the best estimate of intake is known, one may multiply the intake with the dose conversion factor which appears at the top of each table. This procedure should be followed to determine the ultimate dose. The tables provide dose estimation just from one measurement in order to provide early information to indicate if any protective action should be taken.

In order to use the above equation, one needs to know the fraction of intake accumulated in urine. These are found in Ref. 5.

Detail of Calculations

Step 1

$\Delta t_i = t_i - t_{i-1}$ $\quad i = 1$ Sample #1

$\Delta t_1 = 0.2 - 0 = 0.2$ days

$\Delta A_i = C_i \times 1.4$ L/day $\times \Delta t_i$ from Reference Man (14)

$\Delta A_1 = 6{,}100 \times 1.4 \times 0.2 = 1708$ μg

$A_1 = 1700$ Presented in Column #5

Step 2

$\Delta t_i = ti - t_{i-1}$ $\quad i = 2$ Sample #2

$t_2 = 0.6 - 0.2 = 0.4$ days

$\Delta A_i = Ci \times 1.4$ L/day $\times \Delta t_i \quad i = 2$

$\Delta A_2 = (990 \times 1.4 \times 0.4)\ \mu g$

$\Delta A_2 = 554.4$

$A_i = \Delta A_1 + A_2 \ldots . \Delta A_i$

$A_3 = 554.4 + 1708 = 2262 \sim 2300$ Column 5, 2nd row

Step 3

Same as Above

$A_4 = 2500$

$A_5 = 2700$

The Dunning report (6) lists data in mrem/μCi; these have to be converted into Bq of intake to be used in this tabulation. Also, correction for particle size is needed to obtain correct intake value.

PARTICLE-SIZE CORRECTIONS

According to ICRP 30, after a short time post single intake, the following approximate relationship exists between the total body intake retention function (IRF) for aerosols between 0.2 and 10 μm.

$$\frac{IRF\ (AMAD)}{IRF\ (1\ \mu m)} = \sum_T \left[f_{N-P} \times \frac{H_{50T}\ W_T}{\Sigma\ H_{50T}\ W_T} \times \frac{D_{N-P}\ (AMAD)}{D_{N-P}\ (1\ \mu m)} \right.$$

$$+ f_{T-B} \times \frac{H_{50T}\ W_T}{\Sigma\ H_{50T}\ W_T} \times \frac{D_{T-B}\ (AMAD)}{D_{T-B}\ (1\ \mu m)} \qquad (1)$$

$$\left. + f_P \times \frac{H_{50T}\ W_T}{\Sigma\ H_{50T}\ W_T} \times \frac{Dp30\ (AMAD)}{Dp\ (1\ \mu m)} \right]$$

where IRF (AMAD) = Total IRF for inhalation of D, W, Y compound of aerosol of interest.

IRF (1 μm) = Total IRF for 1 μm AMAD particle for D, W, Y

f_{N-P}, f_{T-B}, f_P = The fraction of committed dose equivalent in the tissue T resulting from deposition in the N-P, T-B & P Regions respectively, as defined in ICRP 30.

H_{50} W_T = The weighted committed dose equivalent in Tissue T per unit intake.

D_{N-P}, D_{T-B} and D_P = Regional deposition fractions for an aerosol entering the respiratory tract.

The time when Eq. 1 is valid will differ for the various classes:

Class	Time when Eq. 1 is valid
D	Less than 1 day
W	7 days post intake
Y	9 days post intake

Values for f_{N-P}, f_{T-B}, f_P and H_{50T} W_T are given in supplements of ICRP 30 (3)
D_{N-P}, D_{T-B} and D_P are listed in Table 6 for various AMAD values.

ADDITIONAL COMMENTS

URANIUM

Only intake by inhalation is considered here. Several simplifying assumptions are used in the ICRP 30 model, e.g. the lung clearance classifications (D, W, and Y) are known, and particle size distributions have a characteristic 1.0 μm activity median aerosol dynamic diameter (AMAD). However, very often the actual particle size distribution is not known. Using Reference Man (14), one assumes a daily urinary excretion of 1.4 L/d.

TABLE 6

REGIONAL DEPOSITION FRACTIONS FOR AEROSOLS WITH AMADs BETWEEN 0.2 AND 10 μm. (Ref. 5)

	Aerosol AMAD, μm			
	0.2	0.5	0.7	1
D_{N-P}	4.98E-02	1.61E-01	2.27E-01	3.10E-01
D_{T-B}	8.00E-02	8.00E-02	8.00E-02	8.00E-02
D_P	5.00E-01	3.50E-01	2.99E-01	1.67E-01
Total Deposition	6.30E-01	5.91E-01	6.06E-01	6.68E-01

	Aerosol AMAD, μm			
	2	5	7	10
D_{N-P}	5.00E-01	7.44E-01	8.14E-01	8.75E-01
D_{T-B}	8.00E-02	8.00E-02	8.00E-02	8.00E-02
D_P	1.67E-01	8.80E-02	6.74E-02	4.98E-02
Total Deposition	6.68E-01	9.12E-01	9.61E-01	1.00E-00

For uranium, an appropriate bioassay technique is in vivo lung monitoring for class W and class Y compounds, and urinary measurement, for class D. For class W and Y, the intake retention fraction for the 24-hour urine compartment decreases rapidly, and low levels of natural uranium in urine make it difficult to estimate an accidental exposure. Thus in vivo lung monitoring should be chosen for class W and Y compounds. Later the intake retention fraction for lung is given and finally the dose commitment is calculated.

Because of the long half lives, decay corrections are not needed for U-234, 235 and 238. The best estimate of the intake is calculated first, and the Dunning Report (6) can be used to calculate effective dose equivalent. The Dunning Report gives doses for AMAD values of 0.3, 0.5 and 1.0 μm and the appropriate value must be selected. The tables (Tables 19-29) are set up for 1 μm AMAD.

Table 7 lists internal retention factors (IRF) for the lung for U-2385. The same procedure applies for other uranium isotopes.

HIGHLY ENRICHED MATERIAL

As a special case, a material containing 93% ^{235}U, 6% ^{238}U and 1% ^{233}U was analyzed.

Total Activity Detected in Urine =

activity of U^{235} + activity of U^{238} + activity of U^{234}

$= \lambda_{235} N^{235} + \lambda_{238} N^{238} + \lambda_{234} N^{234}$

TABLE 7

INTERNAL RETENTION FACTORS FOR URANIUM 238 (5)

Time After Intake, Days	Class D IRF		Class W IRF		Class Y IRF	
	Systemic Region	24-Hour Urine	Lungs	24-Hour Urine	Lungs	24-Hour Urine
1	2.22E-01	1.87E-01	2.11E-01	4.13E-02	2.14E-01	2.28E-03
5	1.65E-01	1.31E-02	1.45E-01	2.69E-03	1.53E-01	1.28E-04
10	1.21E-01	7.26E-03	1.32E-01	1.75E-03	1.49E-01	8.26E-05
20	7.36E-02	3.26E-03	1.16E-01	1.03E-03	1.47E-01	4.62E-05
100	1.47E-02	1.11E-04	4.18E-02	2.43E-04	1.35E-01	1.87E-05

Additionally, the ALI's for uranium 238 are 5E+04 Bq for Class D, 3E+04 for Class W and 2E+03 for Class Y aerosols having an AMAD of 1 micrometer. The minimum detection limit for daily urine sampling is typically 7 ug (1.7E-02 Bq), and for in vivo lung monitoring 100 Bq.

$$= \frac{\ln 2 \; N^{235}}{T_{1/2}(235)} + \frac{\ln 2 \; N^{238}}{T_{1/2}(238)} + \frac{\ln 2 \; N^{234}}{T_{1/2}(234)}$$

$$A_{TOTAL} = \frac{\ln 2 \; (0.93)}{2.22 \text{ E16 sec}} + \frac{\ln 2 \; (0.06)}{1.0 \text{ E17 sec}} + \frac{\ln 2 \; (0.01)}{7.7 \text{ E12 sec}} = 9.29 \text{ E-16 Bq/g}$$

Contributions:

$$^{235}A = \frac{A_{TOTAL} \times 100\%}{\lambda_{235} N^{235}} = 3.13\%$$

$$^{234}A = \frac{A_{TOTAL} \times 100\%}{\lambda_{234} N^{234}} = 96.83\%$$

$$^{238}A = \frac{A_{TOTAL} \times 100\%}{\lambda_{238} N^{238}} = 0.045\%$$

Committed Dose equivalent H is calculated as follows:

$$H_{mixture} = H_{234} \times \%A_{234} + H_{235} \%A_{235} + H_{238} \times \%A_{238}$$

U-238 contribution to the total dose is very small and may be neglected. The dose equivalent to the lungs is essentially due to U-234 in the mixture, but because of the U-235 component, the dose in the mixture is about 0.5% lower than from U-234 alone.

For example, at t = 1.00 E-01 days committed dose equivalent for the mixture is 1.31 E-05 Sv per Bq excreted; committed dose equivalent for U-234 at t = 1.00 E-01 day is 1.32 E-05 Sv per Bq excreted. At t = 3.00 E+01 days, committed dose equivalent for mixture is 1.86 E-04 Sv per Bq excreted. Therefore, for the mixture, U-234 data alone may be used and lead to reasonably acceptable results.

PLUTONIUM

Urinary monitoring for Pu-239 is a good choice, if sufficient sensitivity is available. Modern radiochemical separation of Pu in urine, in the presence of uranium, has a minimum detectable activity (MDA) of 90 attocuries per liter for a 24-hour urine sample. ANSI N13.30 (16) has the equations for bioassay. This technique relies on activation by of neutrons and the fissioning of Pu. However, with attocurie sensitivity for urine with 1.0 E-04 to 1.0 E-07 of the activity inhaled, several urinary measurements are needed in order to reduce the order of uncertainty associated with variation of Pu excretion due to diet. Because ALI is based on radiotoxic effects to bone, urinary monitoring is more appropriate than feces monitoring, which may be associated mainly with lung or GI deposition of Pu. (3) Lung counting is not recommended for routine bioassay procedure. The draft ANSI 13.30 standard, "Performance criteria for Radiobioassay," specifies the MDA to be 190 Bq/L of x-rays per nuclear transformation for lung counting for transuranics (16). For the reported L x-ray yield of Pu-239 of 4.24 (5), this corresponds to an MDA of 4.4 kBq. Based upon approximately 15% of intake of Pu of class W and class Y compounds expected to be present in lungs after 7 days, this corresponds to a minimum detectable intake of 2.9E+04 Bq. Class W and class Y ALIs for Pu-239 are respectively 200 Bq and 500 Bq. Minimum detectable intake corresponds to 150 ALI for class W and 56 ALI for class Y compounds of Pu-239. Hence, lung counting is useful only for large accidental exposures. Urinary monitoring is a good way of monitoring, if sufficient sensitivity is available.

ICRP 48 (15) gives a retention model for Pu that is based on data for several mammalian species, including Langham's data for man. This model does not consider excretion explicitly and is not intended as a bioassay model. There are many power function excretion curves (modifications of Langham model) which give similar results. All of these apply to chronic exposures of Pu, which are not of interest here.

The ICRP 30 model gives a fairly good estimate of intakes from excretion fractions, when corrected for particle size and adjusting intake estimates for an accurate time post intake. There is also a correction factor for single versus multiple exposures. However, as Table 8 shows, there are some differences in the fractional retention coefficient f_1 between ICRP 30 and 48.

Best estimate of intake is based on χ^2 statistics. So, even if a different model is adopted for excretion fractions, the method will still be the same.

CONCLUSION

The purpose of this work was the compilation of tables to simplify the estimation of worker's dose commitment and ALI detriment following accidental inhalation of radioactive airborne materials. The following tables, Tables 9-36, present numerical data for this purpose and should serve as reference data for most anticipated inhalation accident scenarios. Appendix B presents the flow sheet used in setting up the computer model employed in these calculations.

TABLE 8

COMPARISON OF PROPOSED VALUES FOR F_1 WITH THOSE RECOMMENDED IN ICRP PUBLICATION 30 (FROM REF. 15)

ELEMENT	TYPE OF EXPOSURE, COMPOUND	$f_1 \times 10^4$ ICRP 48	ICRP 30
Pu	Occupational exposure oxides, including polydisperse oxides	0-1	0-1
	nitrates	1	1
	other compounds or unknown mixtures	10	1
Pu	Population exposure (via food chains) all compounds	10	
Np	Occupational and population exposure all compounds	10	100
Am, Cm, Cf	Occupational and population exposure all compounds	10	5

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APPENDIX A

DOSE AND ALI TABLES

Table 9

DOSE CALCULATION FOR INHALATION OF Co-60 PARTICULATES PER Bq EXCRETED

Co-60 T 1/2 = 1.92 E+03 Days Class - W
AMAD - 1 micron ALI - 6 E+06 Bq F_u = 8.00 E-01

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lungs) = 3.6E-08 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lungs) = 4.3E-09 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	3.35E-03		2.98E+02	4.97E-05	1.07E-05	1.28E-06
2.00E-01	7.09E-03		1.41E+02	2.35E-05	5.07E-06	6.06E-07
3.00E-01	1.01E-02		9.90E+01	1.65E-05	3.56E-06	4.25E-07
4.00E-01	1.29E-02		7.75E+01	1.29E-05	2.79E-06	3.33E-07
5.00E-01	1.57E-02		6.36E+01	1.06E-05	2.29E-06	2.73E-07
6.00E-01	1.81E-02		5.52E+01	9.20E-06	1.98E-06	2.37E-07
7.00E-01	2.02E-02		4.95E+01	8.25E-06	1.78E-06	2.12E-07
8.00E-01	2.23E-02		4.48E+01	7.47E-06	1.61E-06	1.92E-07
9.00E-01	2.42E-02		4.13E+01	6.88E-06	1.48E-06	1.77E-07
1.00E+00	2.59E-02	2.59E-02	3.86E+01	6.43E-06	1.38E-06	1.66E-07
2.00E+00		1.10E-02	9.09E+01	1.51E-05	3.27E-06	3.90E-07
3.00E+00		5.13E-03	1.94E+02	3.24E-05	7.01E-06	8.38E-07
4.00E+00		3.05E-03	3.27E+02	5.46E-05	1.18E-05	1.40E-06
5.00E+00		2.26E-03	4.42E+02	7.37E-05	1.59E-05	1.90E-06
6.00E+00		1.90E-03	5.26E+02	8.77E-05	1.89E-05	2.26E-06
7.00E+00		1.67E-03	5.98E+02	9.98E-05	2.15E-05	2.15E-05
8.00E+00		1.51E-03	6.62E+02	1.10E-04	2.38E-05	2.84E-06
9.00E+00		1.38E-03	7.24E+02	1.20E-04	2.60E-05	3.11E-06
1.00E+01		1.27E-03	7.87E+02	1.31E-04	2.03E-05	3.38E-06
2.00E+01		6.62E-04	1.51E+03	2.51E-04	5.43E-05	6.49E-06
3.00E+01		4.48E-04	2.23E+03	3.72E-04	8.03E-05	9.59E-06
4.00E+01		3.59E-04	2.78E+03	4.64E-04	1.00E-04	1.19E-05
5.00E+01		3.11E-04	3.21E+03	5.35E-04	1.15E-04	1.38E-05
6.00E+01		2.78E-04	3.59E+03	5.99E-04	1.29E-04	1.54E-05
7.00E+01		2.50E-04	4.00E+03	6.66E-04	1.44E-04	1.72E-05
8.00E+01		2.26E-04	4.42E+03	7.37E-04	1.59E-04	1.90E-05
9.00E+01		2.05E-04	4.87E+03	8.13E-04	1.75E-04	2.09E-05
1.00E+02		1.85E-04	5.40E+03	9.00E-04	1.94E-04	2.32E-05

Table 10

DOSE CALCULATION FOR INHALATION OF Co-60 PARTICULATES PER Bq EXCRETED

Co-60 Half Life - 1.22 E+03 Days Class - Y
AMAD - 1 micron ALI - 1.0 E+06 Bq F_u = 8:00 E+01

Critical organ = lungs
Committed Dose Equivalent (EQ) (Lung) = 3.4 E-07 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 4.1 E-08 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake In Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	1.92E-04		5.20E+03	5.20E-03	1.77E-03	2.13E-04
2.00E-01	4.52E-04		2.21E+03	2.21E-03	7.52E-04	9.07E-05
3.00E-01	7.90E-04		1.26E+08	1.26E-03	4.30E-04	5.18E-05
4.00E-01	1.21E-03		8.26E+02	8.26E-04	2.80E-04	3.38E-05
5.00E-01	1.71E-03		5.84E+02	5.84E-04	1.98E-04	2.39E-05
6.00E-01	2.26E-03		4.42E+02	4.42E-04	1.50E-04	1.81E-05
7.00E-01	2.85E-03		3.30E+02	3.50E-04	1.19E-04	1.43E-05
8.00E-01	3.45E-03		2.89E+02	2.89E-04	9.85E-05	1.18E-05
9.00E-01	4.05E-03		2.46E+02	2.46E-04	8.39E-05	1.01E-05
1.00E+00	4.65E-03	4.65E-03	2.15E+02	2.15E-04	7.31E-05	8.81E-06
2.00E+00		3.20E-03	3.12E+02	3.12E-04	1.00E-04	1.28E-05
3.00E+00		2.40E-03	4.16E+02	4.16E-04	1.41E-04	1.70E-05
4.00E+00		1.28E-03	4.81E+02	7.81E-04	2.65E-04	3.20E-05
5.00E+00		8.18E-04	1.22E+03	1.22E-03	4.15E-04	5.01E-05
6.00E+00		6.09E-04	1.64E+03	1.64E-03	5.58E-04	6.73E-05
7.00E+00		4.98E-04	2.00E+03	2.00E-03	6.68E-04	8.23E-05
8.00E+00		4.27E-04	2.43E+03	2.39E-03	7.96E-04	9.60E-05
9.00E+00		3.75E-04	2.66E+03	2.66E-03	9.06E-04	1.09E-04
1.00E+01		3.34E-04	2.99E+03	2.99E-03	1.01E-03	1.22E-04
2.00E+01		1.29E-04	7.75E+03	7.75E-03	2.63E-03	3.17E-04
3.00E+01		6.50E-05	1.53E+04	1.53E-02	5.23E-03	6.30E-04
4.00E+01		4.37E-05	2.28E+04	2.28E-02	7.78E-03	9.38E-04
5.00E+01		3.59E-05	2.78E+04	2.78E-02	9.47E-03	1.14E-03
6.00E+01		3.24E-05	3.08E+04	3.08E-02	1.04E-02	1.26E-03
7.00E+01		3.05E-05	3.27E+04	3.27E-02	1.11E-02	1.34E-03
8.00E+01		2.91E-05	3.43E+04	3.43E-02	1.16E-02	1.40E-03
9.00E+01		2.79E-05	3.58E+04	3.58E-02	1.21E-02	1.46E-03
1.00E+02		2.70E-05	3.70E+04	3.70E-02	1.25E-02	1.51E-03

Table 11

DOSE CALCULATION FOR INHALATION OF Sr-89 PARTICULATES PER Bq EXCRETED

Sr-89 T 1/2 = 5.05 E+01 Days Class - D
AMAD - 1 micron ALI - 0.3E+07 Bq F_u = 8.5 E-01

Critical organ - red marrow
Committed Dose Equivalent (EQ) (Red Marrow) = 5.6E-09 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Red Marrow) = 2.5E-10 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Marrow(Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Marrow(Sv/Bq) Excreted)
1.00E-01	2.57E-02		3.89E+01	1.29E-06	2.17E-07	9.72E-09
2.00E-01	3.81E-02		2.62E+01	8.74E-07	1.46E-07	6.56E-09
3.00E-01	4.55E-02		2.19E+01	7.32E-07	1.23E-07	5.49E-09
4.00E-01	5.21E-02		1.91E+01	6.39E-07	1.07E-07	4.79E-09
5.00E-01	5.82E-02		1.71E+01	5.72E-07	9.62E-08	4.29E-09
6.00E-01	6.40E-02		1.56E+01	5.20E-07	8.75E-08	3.90E-09
7.00E-01	6.96E-02		1.43E+01	4.78E-07	8.04E-08	3.59E-09
8.00E-01	7.51E-02		1.33E+01	4.43E-07	7.45E-08	3.32E-09
9.00E-01	8.05E-02		1.24E+01	4.14E-07	6.95E-08	3.10E-09
1.00E+00	8.57E-02	8.57E-02	1.16E+01	3.88E-07	6.53E-08	2.91E-09
2.00E+00		4.63E-02	2.15E+01	7.19E-07	1.20E-07	5.39E-09
3.00E+00		3.69E-02	2.71E+01	9.03E-07	1.51E-07	6.77E-09
4.00E+00		2.98E-02	3.35E+01	1.11E-06	1.87E-07	8.38E-09
5.00E+00		2.45E-02	4.08E+01	1.36E-06	2.28E-07	1.02E-08
6.00E+00		2.04E-02	4.90E+01	1.63E-06	2.74E-07	1.22E-08
7.00E+00		1.71E-02	5.84E+01	1.94E-06	3.27E-07	1.46E-08
8.00E+00		1.44E-02	6.94E+01	2.31E-06	3.88E-07	1.73E-08
9.00E+00		1.22E-02	8.19E+01	2.73E-06	4.59E-07	2.04E-08
1.00E+01		1.04E-02	9.61E+01	3.20E-06	5.38E-07	2.40E-08
2.00E+01		2.27E-03	4.40E+02	1.46E-05	2.46E-06	1.10E-07
3.00E+01		6.22E-04	1.60E+03	5.35E-05	9.00E-06	4.01E-07

Table 12

DOSE CALCULATION FOR INHALATION OF Sr-89 PARTICULATES PER Bq EXCRETED

Sr-89 T 1/2 = 5.05 E+01 Days Class - Y
AMAD - 1 micron ALI - 5.0 E+06 Bq F_u = 8.5 E-01

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lungs) = 8.4E-08 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lungs) = 1.0E-08 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lungs(Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lungs(Sv/Bq) Excreted)
1.00E-01	4.19E-04		2.38E+03	4.77E-04	2.00E-04	2.38E-05
2.00E-01	5.39E-04		1.85E+03	3.71E-04	1.55E-04	1.85E-05
3.00E-01	6.36E-04		1.57E+03	3.14E-04	1.32E-04	1.57E-05
4.00E-01	7.38E-04		1.35E+03	2.71E-04	1.13E-04	1.35E-05
5.00E-01	8.44E-04		1.18E+03	2.36E-04	9.95E-05	1.18E-05
6.00E-01	9.48E-04		1.05E+03	2.10E-04	8.86E-05	1.05E-05
7.00E-01	1.05E-04		9.52E+02	1.90E-04	8.00E-05	9.52E-06
8.00E-01	1.15E-03		8.69E+02	1.73E-04	7.30E-05	8.69E-06
9.00E-01	1.24E-03		8.06E+02	1.61E-04	6.77E-05	8.06E-06
1.00E+00	1.34E-03	1.34E-03	7.46E+02	1.49E-04	6.26E-05	7.46E-06
2.00E+00		7.89E-04	1.26E+03	2.53E-04	1.06E-05	1.26E-05
3.00E+00		6.22E-04	1.60E+03	3.21E-04	1.35E-04	1.60E-05
4.00E+00		5.09E-04	1.96E+03	3.92E-04	1.64E-04	1.96E-05
5.00E+00		4.22E-04	2.36E+03	4.73E-04	1.99E-04	2.36E-05
6.00E+00		3.54E-04	2.82E+03	5.64E-04	2.37E-04	2.82E-05
7.00E+00		2.99E-04	3.34E+03	6.68E-04	2.80E-04	3.34E-05
8.00E+00		2.55E-04	3.92E+03	7.84E-04	3.29E-04	3.92E-05
9.00E+00		2.18E-04	4.58E+03	9.17E-04	3.85E-04	4.58E-05
1.00E+01		1.87E-04	5.34E+03	1.06E-03	4.49E-04	5.37E-05
2.00E+01		5.07E-05	1.97E+04	3.94E-03	1.65E-03	1.97E-04
3.00E+01		2.32E-05	4.31E+04	8.62E-03	3.62E-03	4.31E-04
4.00E+01		1.75E-05	5.71E+04	1.14E-02	4.80E-03	5.71E-04
5.00E+01		1.63E-05	6.13E+04	1.22E-02	5.15E-03	6.13E-04
6.00E+01		1.59E-05	6.28E+04	1.25E-02	5.28E-03	6.28E-04
7.00E+01		1.58E-05	6.32E+04	1.26E-02	5.31E-03	6.32E-04
8.00E+01		1.57E-05	6.36E+04	1.27E-02	5.35E-03	6.36E-04
9.00E+01		1.56E-05	6.41E+04	1.28E-02	5.38E-03	6.41E-04
1.00E+02		1.56E-05	6.41E+04	1.28E-02	5.38E-03	6.41E-04

Table 13

DOSE CALCULATION FOR INHALATION OF Sr-90 PARTICULATES PER Bq EXCRETED

Sr-90 T 1/2 = 1.06 E+04 Days Class - D
AMAD - 1 micron ALI - 7.0E+05 Bq F_u = 8.50 E-01

Critical organ - red marrow
Committed Dose Equivalent (EQ) (Red Marrow) = 3.3E-07 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Red Marrow) = 4.0E-08 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Marrow(Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Marrow(Sv/Bq) Excreted)
1.00E-01	2.75E-02		3.63E+01	5.19E-05	1.20E-05	1.45E-06
2.00E-01	3.81E-02		2.62E+01	3.74E-05	8.66E-06	1.04E-06
3.00E-01	4.55E-02		2.19E+01	3.13E-05	7.25E-06	8.79E-07
4.00E-01	5.21E-02		1.91E+01	2.74E-05	6.33E-06	7.67E-07
5.00E-01	5.82E-02		1.71E+01	2.45E-05	5.67E-06	6.87E-07
6.00E-01	6.40E-02		1.56E+01	2.23E-05	5.15E-06	6.25E-07
7.00E-01	6.96E-02		1.43E+01	2.05E-05	4.74E-06	5.74E-07
8.00E-01	7.51E-02		1.33E+01	1.90E-05	4.39E-06	5.32E-07
9.00E-01	8.05E-02		1.24E+01	1.77E-05	4.09E-06	4.96E-07
1.00E+00	8.57E-02	8.57E-02	1.16E+01	1.66E-05	3.85E-06	4.66E-07
2.00E+00		4.63E-02	2.15E+01	3.08E-05	7.12E-06	8.63E-07
3.00E+00		3.69E-02	2.71E+01	3.87E-05	8.94E-06	1.08E-06
4.00E+00		2.98E-02	3.35E+01	4.79E-05	1.10E-05	1.34E-06
5.00E+00		2.03E-02	4.92E+01	7.03E-05	1.62E-05	1.97E-06
6.00E+00		1.71E-02	5.84E+01	8.35E-05	1.92E-05	2.33E-06
7.00E+00		1.44E-02	6.94E+01	9.92E-05	2.29E-05	2.77E-06
8.00E+00		1.22E-02	8.19E+01	1.17E-04	2.70E-05	3.27E-06
9.00E+00		1.04E-02	9.61E+01	1.37E-04	3.17E-05	3.84E-06
1.00E+01		2.26E-02	4.42E+02	6.32E-04	1.46E-04	1.76E-05

Table 14

DOSE CALCULATION FOR INHALATION OF Sr-90 PARTICULATES PER Bq EXCRETED

Sr-90 Half Life - 1.06 E+04 Days Class - Y
AMAD - 1 micron ALI - 1 E+05 Bq F_u = 8.50 E-01

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lungs) = 2.9E-06 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lungs) = 3.4E-07 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lungs(Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lungs(Sv/Bq) Excreted)
1.00E-01	4.19E-04		2.38E+03	2.38E-02	6.92E-03	8.11E-04
2.00E-01	5.39E-04		1.85E+03	1.85E-02	5.38E-03	6.30E-04
3.00E-01	6.36E-04		1.57E+03	1.57E-02	4.55E-03	5.34E-04
4.00E-01	7.38E-04		1.35E+03	1.35E-02	3.92E-03	4.60E-04
5.00E-01	8.44E-04		1.18E+03	1.18E-02	3.43E-03	4.02E-04
6.00E-01	9.48E-04		1.05E+03	1.05E-02	3.05E-03	3.58E-04
7.00E-01	1.05E-04		9.52E+02	9.52E-03	2.76E-03	3.23E-04
8.00E-01	1.15E-03		8.69E+02	8.69E-03	2.52E-03	2.95E-04
9.00E-01	1.24E-03		8.06E+02	8.06E-03	2.33E-03	2.74E-04
1.00E+00	1.34E-03	1.34E-03	7.46E+02	7.46E-03	2.16E-03	2.57E-04
2.00E+00		7.89E-04	1.26E+03	1.26E-02	3.67E-03	4.30E-04
3.00E+00		6.22E-04	1.60E+03	1.60E-02	4.66E-03	5.46E-04
4.00E+00		5.09E-04	1.96E+03	1.96E-02	5.69E-03	6.67E-04
5.00E+00		4.22E-04	2.36E+03	2.36E-02	6.87E-03	8.05E-04
6.00E+00		3.54E-04	2.82E+03	2.82E-02	8.19E-03	9.60E-04
7.00E+00		2.99E-04	3.34E+03	3.34E-02	9.69E-03	1.13E-03
8.00E+00		2.55E-04	3.92E+03	3.92E-02	1.13E-02	1.33E-03
9.00E+00		2.18E-04	4.58E+03	4.58E-02	1.33E-02	1.55E-03
1.00E+01		1.87E-04	5.34E+03	1.06E-02	1.55E-02	1.81E-03
2.00E+01		5.07E-05	1.97E+04	1.97E-01	5.71E-02	6.70E-03
3.00E+01		2.32E-05	4.31E+04	4.31E-01	1.25E-01	1.46E-02
4.00E+01		1.75E-05	5.71E+04	5.71E-01	1.65E-01	1.94E-02
5.00E+01		1.63E-05	6.13E+04	6.32E-01	1.77E-01	2.08E-02
6.00E+01		1.59E-05	6.28E+04	6.28E-01	1.82E-01	2.13E-02
7.00E+01		1.58E-05	6.32E+04	6.32E-01	1.83E-01	2.15E-02
8.00E+01		1.57E-05	6.36E+04	6.36E-01	1.84E-01	2.16E-02
9.00E+01		1.56E-05	6.41E+04	6.41E-01	1.85E-01	2.17E-02
1.00E+02		1.56E-05	6.41E+04	1.85E-01	1.85E-01	2.17E-02

Table 15

DOSE CALCULATION FOR INHALATION OF I-125 PARTICULATES PER Bq EXCRETED

I-125 Half Life - 6.01 E+01 Days Class - D
AMAD - 1 micron ALI - 2.0 E+06 Bq F_u = 9.7 E-01

Critical organ - thyroid
Committed Dose Equivalent (EQ) (Thyroid) = 2.2E-07 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Thyroid) = 6.5E-09 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Thyr.(Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Thyr.(Sv/Bq) Excreted)
1.00E-01	5.01E-02		1.97E+01	9.86E-06	4.33E-06	1.28E-07
2.00E-01	1.09E-01		9.17E+00	4.58E-06	2.01E-06	5.96E-08
3.00E-01	1.58E-01		6.32E+00	3.16E-06	1.39E-06	4.11E-08
4.00E-01	2.00E-01		5.00E+00	2.50E-06	1.10E-06	3.25E-08
5.00E-01	2.34E-01		4.27E+00	2.13E-06	9.40E-07	2.77E-08
6.00E-01	2.63E-01		3.80E+00	1.90E-06	8.36E-07	2.47E-08
7.00E-01	2.87E-01		3.48E+00	1.74E-06	7.66E-07	2.26E-08
8.00E-01	3.08E-01		3.24E+00	1.62E-06	7.14E-07	2.11E-08
9.00E-01	3.26E-01		3.06E+00	1.53E-06	6.74E-07	1.99E-08
1.00E+00	3.41E-01	3.41E-01	2.93E+00	1.46E-06	6.45E-07	1.90E-08
2.00E+00		7.63E-02	1.31E+01	6.55E-06	2.88E-06	8.51E-08
3.00E+00		2.15E-02	4.65E+01	2.32E-05	1.02E-05	3.02E-07
4.00E+00		6.51E-03	1.53E+02	7.68E-05	3.37E-05	9.98E-07
5.00E+00		2.08E-03	4.80E+02	2.40E-04	1.05E-04	3.12E-06
6.00E+00		8.09E-04	1.23E+03	6.18E-04	2.71E-04	8.03E-06
7.00E+00		4.75E-04	2.10E+03	1.05E-03	4.63E-04	1.36E-05
8.00E+00		4.12E-04	2.42E+03	1.21E-03	5.33E-04	1.57E-05
9.00E+00		4.25E-04	2.35E+03	1.17E-03	5.17E-04	1.52E-05
1.00E+01		4.57E-04	2.18E+03	1.09E-03	4.81E-04	1.42E-05
2.00E+01		7.31E-04	1.36E+03	6.83E-04	3.00E-04	8.89E-06
3.00E+01		8.54E-04	1.17E+03	5.85E-04	2.57E-04	7.61E-06

Table 16

DOSE CALCULATION FOR INHALATION OF I-131 PARTICULATES PER Bq EXCRETED

I-131 Half Life - 8.04 E+01 Days Class - D
AMAD - 1 micron ALI - 2.0 E+06 Bq F_u = 9.7 E-01

Critical organ - thyroid
Committed Dose Equivalent (EQ) (Thyroid) = 2.9E-07 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Thyroid) = 8.8E-09 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Thyr.(Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Thyr.(Sv/Bq) Excreted)
1.00E-01	5.01E-02		1.99E+01	9.98E-06	5.78E-06	1.75E-07
2.00E-01	1.09E-01		9.17E+00	4.58E-06	2.66E-06	8.07E-08
3.00E-01	1.58E-01		6.32E+00	3.16E-06	1.83E-06	5.56E-08
4.00E-01	2.00E-01		5.00E+00	2.50E-06	1.45E-06	4.40E-08
5.00E-01	2.34E-01		4.27E+00	2.13E-06	1.23E-06	3.76E-08
6.00E-01	2.63E-01		3.80E+00	1.90E-06	1.10E-06	3.34E-08
7.00E-01	2.87E-01		3.48E+00	1.74E-06	1.01E-06	3.06E-08
8.00E-01	3.08E-01		3.24E+00	1.62E-06	9.41E-07	2.85E-08
9.00E-01	3.26E-01		3.06E+00	1.53E-06	8.89E-07	2.69E-08
1.00E+00	3.41E-01	3.41E-04	2.93E+00	1.46E-06	8.50E-07	2.58E-08
2.00E+00		7.63E-02	1.31E+01	6.55E-06	3.80E-06	1.15E-07
3.00E+00		2.15E-02	4.65E+01	2.32E-05	1.34E-05	4.09E-07
4.00E+00		6.51E-03	1.53E+02	7.68E-05	4.45E-05	1.35E-06
5.00E+00		2.08E-03	4.80E+02	2.40E-04	1.39E-04	4.23E-06
6.00E+00		8.09E-04	1.23E+03	6.18E-04	3.58E-04	1.08E-05
7.00E+00		4.75E-04	2.10E+03	1.05E-03	6.10E-04	1.85E-05
8.00E+00		4.12E-04	2.42E+03	1.21E-03	7.03E-04	2.13E-05
9.00E+00		4.25E-04	2.35E+03	1.17E-03	6.82E-04	2.07E-05
1.00E+01		4.57E-04	2.18E+03	1.09E-03	6.34E-04	1.92E-05
2.00E+01		7.31E-04	1.36E+03	6.83E-03	3.96E-04	1.20E-05
3.00E+01		8.54E-04	1.17E+03	5.85E-04	3.39E-04	1.03E-05

Table 17

DOSE CALCULATION FOR INHALATION OF Cs-134 PARTICULATES PER Bq EXCRETED

Cs-134 Half Life - 7.53 E+02 Days Class - D
AMAD - 1 micron ALI - 4.0 E+06 Bq F_u = 8.00 E-01

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lungs) = 1.2E-08 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lungs) = 1.4E-09 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	9.20E-04		1.08E+03	2.71E-04	1.30E-05	1.52E-06
2.00E-01	2.22E-03		4.50E+02	1.12E-04	5.40E-06	6.30E-07
3.00E-01	3.58E-03		2.79E+02	6.98E-05	3.35E-06	3.91E-07
4.00E-01	4.97E-03		2.01E+02	5.03E-05	2.41E-06	2.81E-07
5.00E-01	6.38E-03		1.56E+02	3.91E-05	1.88E-06	2.19E-07
6.00E-01	7.80E-03		1.28E+02	3.20E-05	1.53E-06	1.79E-07
7.00E-01	9.22E-03		1.08E+02	2.71E-05	1.30E-06	1.51E-07
8.00E-01	1.06E-02		9.43E+01	2.35E-05	1.13E-06	1.32E-07
9.00E-01	1.21E-02		8.26E+01	2.06E-05	9.91E-07	1.15E-07
1.00E+00	1.35E-02	1.35E-02	7.40E+01	1.85E-05	8.88E-07	1.03E-07
2.00E+00		1.33E-02	7.51E+01	1.87E-05	9.02E-07	1.05E-07
3.00E+00		1.10E-02	9.09E+01	2.27E-05	1.09E-06	1.27E-07
4.00E+00		8.87E-03	1.12E+02	2.81E-05	1.35E-06	1.57E-07
5.00E+00		7.16E-03	1.39E+02	3.49E-05	1.67E-06	1.95E-07
6.00E+00		5.89E-03	1.69E+02	4.24E-05	2.03E-06	2.37E-07
7.00E+00		4.98E-03	2.00E+02	5.02E-05	2.40E-06	2.81E-07
8.00E+00		4.32E-03	2.31E+02	5.78E-05	2.77E-06	3.24E-07
9.00E+00		3.85E-03	2.59E+02	6.49E-05	3.11E-06	3.63E-07
1.00E+01		3.51E-03	2.84E+02	7.12E-05	3.41E-06	3.98E-07

Table 18

DOSE CALCULATION FOR INHALATION OF Cs-137 PARTICULATES PER Bq EXCRETED

Cs-137 Half Life - 1.10 E+04 Days Class - D
AMAD - 1 micron ALI - 6.0 E+06 Bq F_u = 8.00 E-01

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lungs) = 8.8E-09 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lungs) = 1.1E-09 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	9.20E-04		1.08E+03	1.81E-04	9.56E-06	1.19E-06
2.00E-01	2.22E-03		4.50E+02	7.50E-05	3.96E-06	4.95E-07
3.00E-01	3.58E-03		2.79E+02	4.65E-05	2.45E-06	3.07E-07
4.00E-01	4.97E-03		2.01E+02	3.35E-05	1.77E-06	2.21E-07
5.00E-01	6.38E-03		1.56E+02	2.61E-05	1.37E-06	1.72E-07
6.00E-01	7.80E-03		1.28E+02	2.13E-05	1.12E-06	1.41E-07
7.00E-01	9.22E-03		1.08E+02	1.80E-05	9.54E-07	1.19E-07
8.00E-01	1.06E-02		9.43E+01	1.57E-05	8.30E-07	1.03E-07
9.00E-01	1.21E-02		8.26E+01	1.37E-05	7.27E-07	9.09E-08
1.00E+00	1.35E-02	1.35E-02	7.40E+01	1.23E-05	6.51E-07	8.14E-08
2.00E+00		1.33E-02	7.51E+01	1.25E-05	6.61E-07	8.27E-08
3.00E+00		1.10E-02	9.09E+01	1.51E-05	8.00E-07	1.00E-07
4.00E+00		8.87E-03	1.12E+02	1.87E-05	9.92E-07	1.24E-07
5.00E+00		7.16E-03	1.39E+02	2.32E-05	1.22E-06	1.53E-07
6.00E+00		5.89E-03	1.69E+02	2.82E-05	1.49E-06	1.86E-07
7.00E+00		4.97E-03	2.01E+02	3.35E-05	1.77E-06	2.21E-07
8.00E+00		4.32E-03	2.31E+02	3.85E-05	2.03E-06	2.54E-07
9.00E+00		3.85E-03	2.59E+02	4.32E-05	2.28E-06	2.85E-07
1.00E+01		3.51E-03	2.84E+02	4.74E-05	2.50E-06	3.13E-07

Table 19

DOSE CALCULATION FOR INHALATION OF U-233 PARTICULATES PER Bq EXCRETED

U-233 T 1/2 = 5.79 E+07 Days Class - D
AMAD - 1 micron ALI - 4 E+4 Bq F_u = 1.0 E+00

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lung) = 3.2E-07 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 3.9E-08 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	2.41E-02		41.32	1.03E-03	1.32E-05	1.61E-06
2.00E-01	5.00E-02		20.00	5.00E-04	6.40E-06	7.80E-07
3.00E-01	7.36E-02		13.59	3.40E-04	4.35E-06	5.30E-07
4.00E-01	9.50E-02		10.53	2.63E-04	3.37E-06	4.11E-07
5.00E-01	1.14E-01		8.77	2.19E-04	2.81E-06	3.42E-07
6.00E-01	1.32E-01		7.58	1.90E-04	2.43E-06	2.96E-07
7.00E-01	1.48E-01		6.76	1.69E-04	2.16E-06	2.64E-07
8.00E-01	1.62E-01		6.17	1.54E-04	1.97E-06	2.41E-07
9.00E-01	1.75E-01		5.71	1.43E-04	1.83E-06	2.23E-07
1.00E+00	1.87E-01	1.87E-01	5.35	1.34E-04	1.71E-06	2.09E-07
2.00E+00		7.27E-02	13.76	3.43E-04	4.39E-06	5.37E-07
3.00E+00		3.21E-02	31.15	7.79E-04	9.97E-06	1.21E-06
4.00E+00		1.82E-02	54.95	1.37E-03	1.76E-05	2.14E-06
5.00E+00		1.31E-02	76.34	1.91E-03	2.44E-05	2.98E-06
6.00E+00		1.09E-02	91.74	2.29E-03	2.94E-05	3.52E-06
7.00E+00		9.64E-03	103.73	2.59E-03	3.32E-05	4.05E-06
8.00E+00		8.71E-03	114.81	2.87E-03	3.67E-05	4.48E-06
9.00E+00		7.94E-03	125.94	3.15E-03	4.03E-05	4.91E-06
1.00E+01		7.26E-03	137.74	3.44E-03	4.41E-05	5.37E-06
2.00E+01		3.26E-03	306.75	7.67E-03	9.82E-05	1.19E-06
3.00E+01		1.71E-03	584.79	1.46E-02	1.87E-04	2.29E-05

Table 20

DOSE CALCULATION FOR INHALATION OF U-233 PARTICULATES PER Bq EXCRETED

U-233 T 1/2 = 5.79 E+07 Days Class - W
AMAD - 1 micron ALI - 3 E+04 Bq F_u = 1.0 E+00

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lung) = 1.6E-05 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 1.9E-06 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	6.93E-03		1.44E+02	4.81E-03	2.30E-03	2.74E-04
2.00E-01	1.37E-02		7.29E+02	2.43E-03	1.16E-03	1.38E-04
3.00E-01	1.92E-02		5.20E+01	1.73E-03	8.33E-03	9.89E-05
4.00E-01	2.40E-02		4.16E+01	1.38E-03	6.66E-03	7.91E-05
5.00E-01	2.80E-02		3.57E+01	1.19E-03	5.71E-04	6.78E-05
6.00E-01	3.15E-02		3.71E+01	1.05E-03	5.07E-04	6.03E-05
7.00E-01	3.44E-02		2.90E+01	9.68E-04	4.65E-04	5.52E-05
8.00E-01	3.70E-02		2.70E+01	9.00E-04	4.32E-04	5.13E-05
9.00E-01	3.93E-02		2.54E+01	8.48E-04	4.07E-04	4.38E-05
1.00E+00	4.13E-02	4.13E-02	2.42E+01	8.07E-04	3.87E-04	4.60E-05
2.00E+00		1.09E-02	9.17E+01	3.05E-03	1.46E-03	1.74E-04
3.00E+00		4.72E-03	2.11E+02	7.06E-03	3.38E-03	4.02E-04
4.00E+00		3.22E-03	3.10E+02	1.03E-02	4.96E-03	5.90E-04
5.00E+00		2.69E-03	3.71E+02	1.23E-02	5.94E-03	7.06E-04
6.00E+00		2.40E-03	4.16E+02	1.38E-02	6.66E-03	7.91E-04
7.00E+00		2.19E-03	4.56E+02	1.52E-02	7.30E-03	8.67E-04
8.00E+00		2.02E-03	4.95E+02	1.65E-02	7.92E-03	9.40E-04
9.00E+00		1.88E-03	5.31E+02	1.77E-02	8.51E-03	1.01E-03
1.00E+01		1.75E-03	5.71E+02	1.90E-02	9.14E-03	1.08E-03
2.00E+01		1.03E-03	9.70E+02	3.23E-02	1.55E-02	1.84E-03
3.00E+01		7.28E-04	1.37E+03	4.57E-02	2.19E-02	2.60E-03
4.00E+01		5.75E-04	1.73E+03	5.79E-02	2.78E-02	3.30E-03
5.00E+01		4.80E-04	2.80E+03	6.94E-02	3.33E-02	3.95E-03
6.00E+01		4.11E-04	2.43E+03	8.11E-02	3.89E-02	4.62E-03
7.00E+01		3.57E-04	2.86E+03	9.33E-02	4.48E-02	5.32E-03
8.00E+01		3.12E-04	3.20E+03	1.06E-01	5.12E-02	6.08E-03
9.00E+01		2.75E-04	3.63E+03	1.21E-01	5.81E-02	6.90E-03
1.00E+01		2.43E-04	4.11E+03	1.37E-01	6.58E-02	7.81E-03

Table 21

DOSE CALCULATION FOR INHALATION OF U-234 PARTICULATES PER Bq EXCRETED

U-234 Half Life - 8.94 E+07 Days Class - D
AMAD - 1 micron ALI - 5 E+4 Bq F_u = 1.0 E+00

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lung) = 3.2 x 10-7 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 3.8E-08 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	2.41E-02		41.32	8.26E-04	1.32E-05	1.57E-06
2.00E-01	5.00E-02		20.00	4.00E-04	6.40E-06	7.6 E-07
3.00E-01	7.36E-02		13.59	2.71E-04	4.34E-06	5.16E-07
4.00E-01	9.50E-02		10.53	2.10E-04	3.36E-06	4.00E-07
5.00E-01	1.14E-01		8.77	1.75E-04	2.80E-06	3.33E-07
6.00E-01	1.32E-01		7.58	1.51E-04	2.42E-06	2.88E-07
7.00E-01	1.48E-01		6.76	1.35E-04	2.16E-06	2.56E-07
8.00E-01	1.62E-01		6.17	1.23E-04	1.97E-06	2.34E-07
9.00E-01	1.75E-01		5.71	1.14E-04	1.82E-06	2.16E-07
1.00E+00	1.87E-01	1.87E-01	5.35	1.07E-04	1.71E-06	2.03E-07
2.00E+00		7.27E-02	13.76	2.71E-04	4.34E-06	5.15E-07
3.00E+00		3.21E-02	31.15	6.23E-04	9.96E-06	1.18E-06
4.00E+00		1.82E-02	54.95	1.09E-03	1.75E-05	2.08E-06
5.00E+00		1.31E-02	76.34	1.52E-03	2.44E-05	2.90E-06
6.00E+00		1.09E-02	91.74	1.83E-03	2.93E-05	3.48E-06
7.00E+00		9.64E-03	103.73	2.07E-03	3.31E-05	3.94E-06
8.00E+00		8.71E-03	114.81	2.29E-03	3.36E-05	4.36E-06
9.00E+00		7.94E-03	125.94	2.51E-03	4.03E-05	4.78E-06
1.00E+01		7.26E-03	137.74	2.75E-03	4.40E-05	5.23E-06
2.00E+01		3.26E-03	306.75	6.13E-03	9.81E-05	1.16E-05
3.00E+01		1.71E-03	584.79	1.16E-02	1.87E-04	2.22E-05

Table 22

DOSE CALCULATION FOR INHALATION OF U-234 PARTICULATES PER Bq EXCRETED

U-234 T 1/2 = 8.94 E+07 Days Class - W
AMAD - 1 micron ALI - 1.0E+03 Bq F_u = 1.0 E+00

Critical organ - lungs
Committed Dose Equivalent (EQ) (Lung) = 1.6E-05 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 1.9E-06 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	6.93E-03		1.44E+02	4.81E-03	2.30E-03	2.74E-04
2.00E-01	1.37E-02		7.29E+02	2.43E-03	1.16E-03	1.38E-04
3.00E-01	1.92E-02		5.20E+01	1.73E-03	8.33E-03	9.89E-05
4.00E-01	2.40E-02		4.16E+01	1.38E-03	6.66E-04	7.91E-05
5.00E-01	2.80E-02		3.57E+01	1.19E-03	5.71E-04	6.78E-05
6.00E-01	3.15E-02		3.71E+01	1.05E-03	5.07E-04	6.03E-05
7.00E-01	3.44E-02		2.90E+01	9.68E-04	4.65E-04	5.52E-05
8.00E-01	3.70E-02		2.70E+01	9.00E-04	4.32E-04	5.13E-05
9.00E-01	3.93E-02		2.54E+01	8.48E-04	4.07E-04	4.38E-05
1.00E+00	4.13E-02	4.13E-02	2.42E+01	8.07E-04	3.87E-04	4.60E-05
2.00E+00		1.09E-02	9.17E+01	3.05E-03	1.46E-03	1.74E-04
3.00E+00		4.72E-03	2.11E+02	7.06E-03	3.38E-03	4.02E-04
4.00E+00		3.22E-03	3.10E+02	1.03E-02	4.96E-03	5.90E-04
5.00E+00		2.69E-03	3.71E+02	1.23E-02	5.94E-03	7.06E-04
6.00E+00		2.40E-03	4.16E+02	1.38E-02	6.66E-03	7.91E-04
7.00E+00		2.19E-03	4.56E+02	1.52E-02	7.30E-03	8.67E-04
8.00E+00		2.02E-03	4.95E+02	1.65E-02	7.92E-03	9.40E-04
9.00E+00		1.88E-03	5.31E+02	1.77E-02	8.51E-03	1.01E-03
1.00E+01		1.75E-03	5.71E+02	1.90E-02	9.14E-03	1.08E-03
2.00E+01		1.03E-03	9.70E+02	3.23E-02	1.55E-02	1.84E-03
3.00E+01		7.28E-04	1.37E+03	4.57E-02	2.19E-02	2.60E-03
4.00E+01		5.75E-04	1.73E+03	5.79E-02	2.78E-02	3.30E-03
5.00E+01		4.80E-04	2.80E+03	6.94E-02	3.33E-02	3.95E-03
6.00E+01		4.11E-04	2.43E+03	8.11E-02	3.89E-02	4.62E-03
7.00E+01		3.57E-04	2.86E+03	9.33E-02	4.48E-02	5.32E-03
8.00E+01		3.12E-04	3.20E+03	1.06E-01	5.12E-02	6.08E-03
9.00E+01		2.75E-04	3.63E+03	1.21E-01	5.81E-02	6.90E-03
1.00E+01		2.43E-04	4.11E+03	1.37E-01	6.58E-02	7.81E-03

Table 23

DOSE CALCULATION FOR INHALATION OF U-234 PARTICULATES PER Bq EXCRETED

U-234 Half Life - 8.94 E+07 Days Class - Y
AMAD - 1 micron ALI - 1.0 E+03 Bq F_u = 1:00 E+00

Critical organ = lungs
Committed Dose Equivalent (EQ) (Lung) = 3.0 E-04 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 3.6 E-05 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake In Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	3.80E-04		2.63E+03	2.63E+00	7.89E-01	9.47E-02
2.00E-01	7.49E-04		1.33E+03	1.33E+00	4.00E-01	4.80E-02
3.00E-01	1.05E-03		9.52E+02	9.52E-01	2.85E-01	3.42E-02
4.00E-01	1.31E-03		7.63E+02	7.63E-01	2.29E-01	2.74E-02
5.00E-01	1.53E-03		6.53E+02	6.53E-01	1.96E-01	2.35E-02
6.00E-01	1.71E-03		5.84E+02	5.84E-01	1.75E-01	2.10E-02
7.00E-01	1.87E-03		5.34E+02	5.34E-01	1.60E-01	1.92E-02
8.00E-01	2.01E-03		4.97E+02	4.97E-01	1.49E-01	1.79E-02
9.00E-01	2.13E-03		4.69E+02	4.69E-01	1.40E-01	1.69E-02
1.00E+00	2.23E-03	2.23E-03	4.48E+02	4.48E-01	1.34E-01	1.61E-02
2.00E+00		5.49E-04	1.82E+03	1.82E+00	5.46E-01	6.55E-02
3.00E+00		2.30E-04	4.34E+03	4.34E+00	1.30E+00	1.56E-01
4.00E+00		1.57E-04	6.36E+03	6.36E+00	1.91E+00	2.29E-01
5.00E+00		1.31E-04	7.63E+03	7.63E+00	2.29E+00	2.74E-01
6.00E+00		1.17E-04	8.54E+03	8.54E+00	2.56E+00	3.07E-01
7.00E+00		1.07E-04	9.34E+03	9.34E+00	2.80E+00	3.36E-01
8.00E+00		9.81E-05	1.01E+04	1.01E+01	3.05E+00	3.66E-01
9.00E+00		9.07E-05	1.10E+04	1.10E+01	3.30E+00	3.96E-01
1.00E+01		8.42E-05	1.18E+04	1.18E+01	3.56E+00	4.27E-01
2.00E+01		4.69E-05	2.13E+04	2.13E+01	6.39E+00	7.67E-01
3.00E+01		3.27E-05	3.05E+04	3.05E+01	9.17E+00	1.10E+00
4.00E+01		2.65E-05	3.77E+04	3.77E+01	1.13E+01	1.35E+00
5.00E+01		2.34E-05	4.27E+04	4.27E+01	1.28E+01	1.53E+00
6.00E+01		2.20E-05	4.54E+04	4.54E+01	1.36E+01	1.63E+00
7.00E+01		2.04E-05	4.90E+04	4.90E+01	1.47E+01	1.76E+00
8.00E+01		1.96E-05	5.10E+04	5.10E+01	1.53E+01	1.83E+00
9.00E+01		1.91E-05	5.23E+04	5.23E+01	1.57E+01	1.88E+00
1.00E+02		1.87E-05	5.34E+04	5.34E+01	1.60E+01	1.92E+00

Table 24

DOSE CALCULATION FOR INHALATION OF U-235 PARTICULATES PER Bq EXCRETED

U-235 T 1/2 = 2.57 E+11 Days Class - D
AMAD - 1 micron ALI - 5 E+04 Bq F_u = 1.00 E+00

Critical organ = lungs
Committed Dose Equivalent (EQ) (Lung) = 2.8E-07 Sv/Bq inhaled
Wt. Committed Dose Equivalent (EQ) (Lung) = 3.5E-08 Sv/Bq inhaled

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	2.41E-02		41.32	8.26E-04	1.19E-05	1.44E-06
2.00E-01	5.00E-02		20.00	4.00E-04	5.80E-06	7.00E-07
3.00E-01	7.36E-02		13.59	2.71E-04	3.94E-06	4.75E-07
4.00E-01	9.50E-02		10.53	2.10E-04	3.05E-06	3.68E-07
5.00E-01	1.14E-01		8.77	1.75E-04	2.54E-06	3.06E-07
6.00E-01	1.32E-01		7.58	1.51E-04	2.19E-06	2.65E-07
7.00E-01	1.48E-01		6.76	1.35E-04	1.96E-06	2.36E-07
8.00E-01	1.62E-01		6.17	1.23E-04	1.78E-06	2.15E-07
9.00E-01	1.75E-01		5.71	1.14E-04	1.65E-06	1.99E-07
1.00E+00	1.87E-01	1.87E-01	5.35	1.07E-04	1.55E-06	1.87E-07
2.00E+00		7.27E-02	13.76	2.75E-04	3.99E-06	4.81E-07
3.00E+00		3.21E-02	31.15	6.23E-04	9.03E-06	1.09E-06
4.00E+00		1.82E-02	54.95	1.09E-03	1.59E-05	1.92E-06
5.00E+00		1.31E-02	76.34	1.52E-03	2.21E-05	2.67E-06
6.00E+00		1.09E-02	91.74	1.83E-03	2.66E-05	3.21E-06
7.00E+00		9.64E-03	103.73	2.07E-03	3.00E-05	3.63E-06
8.00E+00		8.71E-03	114.81	2.29E-03	3.32E-05	4.01E-06
9.00E+00		7.94E-03	125.94	2.51E-03	3.65E-05	4.40E-06
1.00E+01		7.26E-03	137.74	2.75E-03	3.99E-05	4.82E-06
2.00E+01		3.26E-03	306.75	6.13E-03	8.89E-05	1.07E-05
3.00E+01		1.71E-03	584.79	1.16E-03	1.69E-04	2.04E-05

Table 25

DOSE CALCULATION FOR INHALATION OF U-235 PARTICULATES PER Bq EXCRETED

U-235 T 1/2 = 2.57 E+11 Days Class - W
AMAD - 1 micron ALI - 3 E+04 Bq F_u = 1.00 E+00

Critical organ = lungs
Committed Dose Equivalent (EQ) (Lung) = 1.5E-05 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 1.8E-06 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	6.93E-03		1.44E+02	4.81E-03	2.16E-03	2.59E-04
2.00E-01	1.37E-02		7.29E+01	2.43E-03	1.09E-03	1.31E-04
3.00E-01	1.92E-02		5.20E+01	1.73E-03	7.81E-04	9.37E-05
4.00E-01	2.40E-02		4.16E+01	1.38E-03	6.25E-04	7.50E-05
5.00E-01	2.80E-02		3.57E+01	1.19E-03	5.35E-04	6.42E-05
6.00E-01	3.15E-02		3.17E+01	1.05E-03	4.76E-04	5.71E-05
7.00E-01	3.44E-02		2.90E+01	9.68E-04	4.36E-04	5.23E-05
8.00E-01	3.70E-02		2.70E+01	9.00E-04	4.05E-04	4.86E-05
9.00E-01	3.93E-02		2.54E+01	8.48E-04	3.81E-04	4.58E-05
1.00E+00	4.13E-02	4.13E-02	2.42E+01	8.07E-04	3.63E-04	4.35E-05
2.00E+00		1.09E-02	9.17E+01	3.05E-03	1.37E-03	1.65E-04
3.00E+00		4.72E-03	2.11E+02	7.06E-03	3.17E-03	3.81E-04
4.00E+00		3.22E-03	3.10E+02	1.03E-02	4.65E-03	5.59E-04
5.00E+00		2.69E-03	3.71E+02	1.23E-02	5.57E-03	6.69E-04
6.00E+00		2.40E-03	4.16E+02	1.38E-02	6.25E-03	7.50E-04
7.00E+00		2.19E-03	4.56E+02	1.52E-02	6.84E-03	8.21E-04
8.00E+00		2.02E-03	4.95E+02	1.65E-02	7.42E-03	8.91E-04
9.00E+00		1.80E-03	5.31E+02	1.77E-02	7.97E-03	9.57E-04
1.00E+01		1.75E-03	5.71E+02	1.90E-02	8.75E-03	1.02E-03
2.00E+01		1.03E-03	9.70E+02	3.23E-02	1.45E-02	1.74E-03
3.00E+01		7.28E-04	1.37E+03	4.57E-02	2.06E-02	2.47E-03
4.00E+01		5.75E-04	1.73E+03	5.79E-02	2.60E-02	3.13E-03
5.00E+01		4.80E-04	2.08E+03	6.94E-02	3.12E-02	3.74E-03
6.00E+01		4.11E-04	2.43E+03	8.11E-02	3.64E-02	4.37E-03
7.00E+01		3.57E-04	2.80E+03	9.33E-02	4.20E-02	5.04E-03
8.00E+01		3.12E-04	3.20E+03	1.06E-01	4.81E-02	5.76E-03
9.00E+01		2.75E-04	3.63E+03	1.21E-01	5.45E-02	6.54E-03
1.00E+02		2.43E-04	4.11E+03	1.37E-01	6.17E-02	7.40E-03

Table 26

DOSE CALCULATION FOR INHALATION OF U-235 PARTICULATES FOR Bq EXCRETED

U-235 Half Life - 2.57 E+11 Days Class - Y
AMAD - 1 micron ALI - 2 E+03 Bq F_u = 1.00 E+00

Critical organ = lungs
Committed Dose Equivalent (EQ) (Lung) = 2.8 E-04 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 3.3 E-05 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	3.80E-04		2.63E+03	1.31E+00	7.36E-01	8.68E-02
2.00E-01	7.49E-04		1.33E+03	6.67E-01	3.77E-01	4.40E-02
3.00E-01	1.05E-03		9.52E+02	4.76E-01	2.66E-01	3.14E-02
4.00E-01	1.31E-03		7.63E+02	3.81E-01	2.13E-01	2.51E-02
5.00E-01	1.53E-03		6.53E+02	3.26E-01	1.83E-01	2.15E-02
6.00E-01	1.71E-03		5.84E+02	2.92E-01	1.63E-01	1.92E-02
7.00E-01	1.87E-03		5.34E+02	2.67E-01	1.49E-01	1.76E-02
8.00E-01	2.01E-03		4.97E+02	2.48E-01	1.39E-01	1.64E-02
9.00E-01	2.13E-03		4.69E+02	2.34E-01	1.31E-01	1.54E-02
1.00E+00	2.23E-03	2.23E-03	4.48E+02	2.24E-01	1.95E-01	1.47E-02
2.00E+00		5.49E-04	1.82E+03	9.10E-01	5.10E-01	6.01E-02
3.00E+00		2.30E-04	4.34E+03	2.17E+00	1.21E+00	1.43E-01
4.00E+00		1.57E-04	6.36E+03	3.18E+00	1.78E+00	2.10E-01
5.00E+00		1.31E-04	7.63E+03	3.81E+00	2.13E+00	2.51E-01
6.00E+00		1.17E-04	8.54E+03	4.27E+00	2.39E+00	2.82E-01
7.00E+00		1.07E-04	9.04E+03	4.67E+00	2.61E+00	3.08E-01
8.00E+00		9.81E-05	1.01E+04	5.09E+00	2.58E+00	3.36E-01
9.00E+00		9.07E-05	1.10E+04	5.51E+00	3.08E+00	5.63E-01
1.00E+01		8.42E-05	1.18E+04	5.93E+00	3.32E+00	3.91E-01
2.00E+01		4.69E-05	2.13E+04	1.06E+01	5.97E+00	7.03E-01
3.00E+01		3.27E-05	3.05E+04	1.52E+01	8.56E+00	1.00E+00
4.00E+01		2.65E-05	3.77E+04	1.88E+01	1.05E+01	1.24E+00
5.00E+01		2.34E-05	4.27E+04	2.13E+01	1.19E+01	1.41E+00
6.00E+01		2.19E-05	4.56E+04	2.28E+01	1.27E+01	1.50E+00
7.00E+01		2.04E-05	4.90E+04	2.45E+01	1.37E+01	1.61E+00
8.00E+01		1.96E-05	5.10E+04	2.55E+01	1.42E+01	1.68E+00
9.00E+01		1.91E-05	5.23E+04	2.61E+01	1.46E+01	1.72E+00
1.00E+02		1.87E-05	5.34E+04	2.67E+01	1.49E+01	1.76E+00

Table 27

DOSE CALCULATION FOR INHALATION OF U-238 PARTICULATES PER Bq EXCRETED

U-238 Half Life - 1.64 E+12 Days Class - D
AMAD - 1 micron ALI - 5 E+4 Bq F_u = 1.0 E+00

Critical organ = lungs
Committed Dose Equivalent (EQ) (Lung) = 2.8E-07 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 3.4E-08 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	2.41E-02		41.32	8.26E-04	1.16E-05	1.40E-06
2.00E-01	5.00E-02		20.00	4.00E-04	5.60E-06	6.80E-07
3.00E-01	7.36E-02		13.59	2.71E-04	3.81E-06	4.62E-07
4.00E-01	9.50E-02		10.53	2.11E-04	2.94E-06	3.58E-07
5.00E-01	1.14E-01		8.77	1.75E-04	2.46E-06	2.98E-07
6.00E-01	1.32E-01		7.58	1.51E-04	2.12E-06	2.58E-07
7.00E-01	1.48E-01		6.76	1.35E-04	1.89E-06	2.30E-07
8.00E-01	1.62E-01		6.17	1.23E-04	1.73E-06	2.10E-07
9.00E-01	1.75E-01		5.71	1.14E-04	1.60E-06	1.94E-07
1.00E+00	1.87E-01	1.87E-01	5.35	1.07E-04	1.50E-06	1.82E-07
2.00E+00		7.27E-02	13.76	2.75E-04	3.84E-06	9.67E-07
3.00E+00		3.21E-02	31.15	6.23E-04	8.72E-06	1.06E-06
4.00E+00		1.82E-02	54.95	1.10E-03	1.54E-05	1.87E-06
5.00E+00		1.31E-02	76.34	1.53E-03	2.14E-05	2.60E-06
6.00E+00		1.09E-02	91.74	1.83E-03	2.57E-05	3.12E-06
7.00E+00		9.64E-03	103.73	2.07E-03	2.90E-05	3.53E-06
8.00E+00		8.71E-03	114.81	2.30E-03	3.21E-05	3.9 E-06
9.00E+00		7.94E-03	125.94	2.52E-03	3.53E-05	4.28E-06
1.00E+01		7.26E-03	137.74	2.75E-03	3.86E-05	4.68E-06
2.00E+01		3.26E-03	306.75	6.14E-03	8.59E-05	1.04E-05
3.00E+01		1.71E-03	584.79	1.17E-03	1.64E-04	1.99E-05

Table 28

DOSE CALCULATION FOR INHALATION OF U-238 PARTICULATES PER Bq EXCRETED

U-238 Half Life - 1.64 E+12 days Class - W
AMAD - 1 micron ALI - 3 E+04 Bq F_u = 1.0 E+00

Critical organ = lungs
Committed Dose Equivalent (EQ) (Lung) = 1.4E-05 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Lung) = 1.7E-06 Sv/Bq

T Days	Fraction Of Intake In Accumulated Urine	Fraction of Intake In Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction Of ALI Per Bq Excreted	Committed Dose Equiv. Lung (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Lung (Sv/Bq) Excreted)
1.00E-01	6.93E-03		1.44E+02	4.81E-03	2.02E-03	2.45E-04
2.00E-01	1.37E-02		7.29E+01	2.43E-03	1.02E-03	1.24E-04
3.00E-01	1.92E-02		5.20E+01	1.73E-03	7.29E-04	8.85E-05
4.00E-01	2.40E-02		4.16E+01	1.38E-03	5.83E-04	7.08E-05
5.00E-01	2.80E-02		3.57E+01	1.19E-03	4.79E-04	6.07E-05
6.00E-01	3.15E-02		3.17E+01	1.05E-03	4.44E-04	5.39E-05
7.00E-01	3.44E-02		2.90E+01	9.68E-04	4.06E-04	4.74E-05
8.00E-01	3.70E-02		2.70E+01	9.00E-04	3.78E-04	4.59E-05
9.00E-01	3.93E-02		2.54E+01	8.48E-04	3.56E-04	4.32E-05
1.00E+00	4.13E-02	4.13E-02	2.42E+01	8.07E-04	3.38E-04	4.11E-05
2.00E+00		1.09E-02	9.17E+01	3.05E-03	1.28E-03	1.55E-04
3.00E+00		4.72E-02	2.11E+02	7.06E-03	2.96E-03	3.60E-04
4.00E+00		3.22E-02	3.10E+02	1.03E-02	4.34E-03	5.27E-04
5.00E+00		2.96E-03	3.71E+02	1.23E-02	5.20E-03	6.31E-04
6.00E+00		2.40E-03	4.16E+02	1.38E-02	5.83E-03	7.08E-04
7.00E+00		2.19E-03	4.56E+02	1.52E-02	6.39E-03	7.76E-04
8.00E+00		2.02E-03	4.95E+02	1.65E-02	6.93E-03	8.41E-04
9.00E+00		1.88E-03	5.31E+02	1.77E-02	7.44E-03	9.04E-04
1.00E+01		1.75E-03	5.71E+02	1.90E-02	8.00E-03	9.71E-04
2.00E+01		1.03E-03	9.70E+02	3.23E-02	1.35E-02	1.65E-03
3.00E+01		7.28E-04	1.37E+03	4.57E-02	1.92E-02	2.33E-03
4.00E+01		5.75E-04	1.73E+03	5.79E-02	2.43E-02	2.95E-03
5.00E+01		4.80E-04	2.08E+03	6.94E-02	2.91E-02	3.54E-03
6.00E+01		4.11E-04	2.43E+03	8.11E-02	3.40E-02	4.13E-03
7.00E+01		3.57E-04	2.80E+03	9.34E-02	3.92E-02	4.76E-03
8.00E+01		3.12E-04	3.20E+03	1.06E-01	4.48E-02	5.44E-03
9.00E+01		2.75E-04	3.63E+03	1.21E-01	5.09E-02	6.18E-03
1.00E+02		2.43E-04	4.11E+03	1.37E-01	5.76E-02	6.99E-03

Table 29

DOSE CALCULATION FOR INHALATION OF U-238 PARTICULATES PER Bq EXCRETED

U-238 Half Life - 1.64 E+12 Days Class - Y
AMAD - 1 micron ALI - 2 E+03 Bq F_u = 1.00E+00

Critical organ - bone surface
Committed Dose Equivalent (EQ) (Bone) = 2.7E-04 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Bone) = 3.2E-05 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI per Bq Excreted	Committed Dose Equiv. Bone (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Bone (Sv/Bq) Excreted)
1.00E-01	3.80E-04		2.63E+03	1.31E+00	7.10E-01	8.42E-02
2.00E-01	7.49E-04		1.33E+03	6.67E-01	3.60E-01	4.27E-02
3.00E-01	1.05E-03		9.52E+02	4.76E-01	2.57E-01	3.04E-02
4.00E-01	1.31E-03		7.63E+02	3.81E-01	2.06E-01	2.44E-02
5.00E-01	1.53E-03		6.53E+02	3.26E-01	1.76E-01	2.09E-02
6.00E-01	1.71E-03		5.84E+02	2.92E-01	1.57E-01	1.87E-02
7.00E-01	1.87E-03		5.34E+02	2.07E-01	1.44E-01	1.71E-02
8.00E-01	2.01E-03		4.97E+02	2.48E-01	1.34E-01	1.59E-02
9.00E-01	2.13E-03		4.69E+02	2.34E-01	1.26E-01	1.50E-02
1.00E+00	2.23E-03	2.23E-03	4.48E+02	2.24E-01	1.21E-01	1.43E-02
2.00E+00		5.49E-03	1.82E+02	9.10E-01	4.91E-01	5.82E-02
3.00E+00		2.30E-04	4.34E+03	2.17E+00	1.17E+00	1.39E-01
4.00E+00		1.57E-04	6.36E+03	3.18E+00	1.71E+00	2.03E-01
5.00E+00		1.31E-04	7.36E+03	3.81E+00	2.06E+00	2.44E-01
6.00E+00		1.17E-04	8.54E+03	4.27E+00	2.30E+00	2.73E-01
7.00E+00		1.07E-04	9.34E+03	4.67E+00	2.52E+00	2.99E-01
8.00E+00		9.81E-05	1.02E+04	5.09E+00	2.75E+00	3.26E-01
9.00E+00		9.07E-05	1.10E+04	5.51E+00	2.97E+00	3.52E-01
1.00E+01		8.42E-05	1.18E+04	5.93E+00	3.20E+00	3.80E-01
2.00E+01		4.69E-05	2.13E+04	1.06E+01	5.75E+00	6.82E-01
3.00E+01		3.27E-05	3.05E+04	1.52E+01	8.25E+00	9.78E-01
4.00E+01		2.65E-05	3.77E+04	1.88E+01	1.01E+01	1.20E+00
5.00E+01		2.34E-05	4.27E+04	2.13E+01	1.15E+01	1.36E+00
6.00E+01		2.19E-05	4.56E+04	2.28E+01	1.23E+01	1.46E+00
7.00E+01		2.04E-05	4.90E+04	2.45E+01	1.32E+01	1.56E+00
8.00E+01		1.96E-05	5.10E+04	2.55E+01	1.37E+01	1.63E+00
9.00E+01		1.91E-05	5.23E+04	2.61E+01	1.41E+01	1.67E+00
1.00E+02		1.87E-05	5.34E+04	2.67E+01	1.44E+01	1.71E+00

Table 30

DOSE CALCULATION FOR INHALATION OF Pu-238 PARTICULATES PER BQ EXCRETED

Pu-238 Half Life - 3.20 E+04 Days Class - W
AMAD - 1 micron ALI - 2 E+02 Bq F_u = 5.4 E-01

Critical organ - bone surface
Committed Dose Equivalent (EQ) (Bone) = 2.2E-03 Sv/Bq
Wt. Committed Dose Equivalent (Eq) (Bone) = 6.6E-05 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction Of ALI Per Bq Excreted	Fraction Dose Equiv. Bone (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Bone (Sv/Bq) Excreted)
1.00E-00	3.05E-05		3.27E+04	1.63E+02	7.21E+01	2.16E+00
2.00E-00	6.46E-05		1.54E+04	7.73E+02	3.40E+01	1.02E+00
3.00E-00	9.69E-05		1.03E+04	5.15E+01	2.27E+01	6.81E-01
4.00E-00	1.28E-04		7.81E+03	3.90E+01	1.71E+01	5.15E-01
5.00E-00	1.57E-04		6.36E+03	3.18E+01	1.40E+01	4.20E-01
6.00E-00	1.85E-04		5.40E+03	2.70E+01	1.18E+01	3.56E-01
7.00E-00	2.11E-04		4.73E+03	2.36E+01	1.09E+01	3.12E-01
8.00E-00	2.36E-04		4.23E+03	2.11E+01	9.32E+00	2.79E-01
9.00E-00	2.60E-04		3.84E+03	1.92E+01	8.46E+00	2.53E-01
1.00E+00	2.83E-04	2.83E-04	3.53E+03	1.76E+01	7.77E+00	2.31E-01
2.00E+00		1.76E-04	5.68E+03	2.84E+01	1.25E+01	3.75E-01
3.00E+00		1.12E-04	8.92E+03	4.46E+01	1.96E+01	5.89E-01
4.00E+00		7.53E-05	1.32E+04	6.64E+01	2.92E+01	8.76E-01
5.00E+00		5.39E-05	1.85E+04	9.27E+01	4.08E+01	1.22E+00
6.00E+00		4.15E-05	2.40E+04	1.20E+02	5.30E+01	1.59E+00
7.00E+00		3.42E-05	2.92E+04	1.46E+02	6.43E+01	1.92E+00
8.00E+00		2.98E-05	3.55E+04	1.67E+02	7.38E+01	2.21E+00
9.00E+00		2.71E-05	3.69E+04	1.84E+02	8.11E+01	2.43E+00
1.00E+01		2.54E-05	3.93E+04	1.96E+02	8.66E+01	2.59E+00
2.00E+01		2.01E-05	4.97E+04	2.48E+02	1.09E+02	3.28E+00
3.00E+01		1.76E-05	5.68E+04	2.84E+02	1.25E+02	3.75E+00
4.00E+01		1.58E-05	6.32E+04	3.16E+02	1.39E+02	4.17E+00
5.00E+01		1.45E-05	6.89E+04	3.44E+02	1.51E+02	4.55E+00
6.00E+01		1.36E-05	7.35E+04	3.67E+02	1.61E+02	4.85E+00
7.00E+01		1.28E-05	7.81E+04	3.90E+02	1.71E+02	5.15E+00
8.00E+01		1.22E-05	8.19E+04	4.09E+02	1.80E+02	5.40E+00
9.00E+01		1.16E-05	8.62E+04	4.31E+02	1.89E+02	5.68E+00
1.00E+02		1.11E-05	9.00E+04	4.50E+02	1.98E+02	5.94E+00

Table 31

DOSE CALCULATION FOR INHALATION OF Pu-238 PARTICULATES PER Bq EXCRETED

Pu-238 Half Life - 2.20 E+04 Days Class - Y
AMAD - 1 micron ALI - 6 E+02 Bq F_u = 5.4 E-01

Critical organ - bone surface
Committed Dose Equivalent (EQ) (Bone) = 6.6E-05 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Bone) = 8.0E-06 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake In Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Bone (Sv/Bq Excreted)	Wtd.Committed Dose Equiv. Bone (Sv/Bq Excreted)
1.00E-01	1.68E-06		5.95E+05	9.92E+02	3.92E+01	4.76E+00
2.00E-01	3.55E-06		2.81E+05	4.69E+02	1.85E+01	2.25E+00
3.00E-01	5.32E-06		1.87E+05	3.13E+02	1.24E+01	1.50E+00
4.00E-01	7.01E-06		1.42E+05	2.37E+02	9.41E+00	1.14E+00
5.00E-01	8.61E-06		1.16E+05	1.93E+02	7.66E+00	9.92E-01
6.00E-01	1.01E-05		9.90E+04	1.65E+02	6.53E+00	7.92E-01
7.00E-01	1.16E-05		8.62E+04	1.43E+02	5.69E+00	6.89E-01
8.00E-01	1.30E-05		7.69E+04	1.28E+02	5.07E+00	6.15E-01
9.00E-01	1.43E-05		6.99E+04	1.16E+02	4.61E+00	5.59E-01
1.00E+00	1.55E-05	1.55E-05	6.45E+04	1.07E+02	4.25E+00	5.16E-01
2.00E+00		9.64E-06	1.03E+05	1.72E+02	6.89E+00	8.29E-01
3.00E+00		6.09E-06	1.64E+05	2.73E+02	1.08E+01	1.31E+00
4.00E+00		4.09E-06	2.44E+05	4.07E+02	1.61E+01	1.95E+00
5.00E+00		2.87E-06	3.48E+05	5.80E+02	2.29E+01	2.78E+00
6.00E+00		2.18E-06	4.58E+05	7.64E+02	3.02E+01	3.66E+00
7.00E+00		1.78E-06	5.61E+05	9.36E+02	3.70E+01	4.49E+00
8.00E+00		1.53E-06	6.53E+05	1.08E+03	4.31E+01	5.22E+00
9.00E+00		1.38E-06	7.24E+05	1.20E+03	4.78E+01	5.79E+00
1.00E+01		1.29E-06	7.75E+05	1.29E+03	5.11E+01	6.20E+00
2.00E+01		1.00E-06	1.00E+06	1.66E+03	6.60E+01	8.66E+00
3.00E+01		8.80E-06	1.13E+06	1.89E+03	7.49E+01	9.09E+01
4.00E+01		8.04E-06	1.24E+06	2.07E+03	8.20E+01	9.95E+01
5.00E+01		7.56E-07	1.32E+06	2.20E+03	8.73E+01	1.05E+01
6.00E+01		7.27E-07	1.37E+06	2.29E+03	9.07E+01	1.10E+01
7.00E+01		7.11E-07	1.40E+06	2.34E+03	9.28E+01	1.12E+01
8.00E+01		7.02E-07	1.42E+06	2.37E+03	9.40E+01	1.13E+01
9.00E+01		6.98E-07	1.43E+06	2.38E+03	9.45E+01	1.14E+01
1.00E+01		6.97E-07	1.93E+06	2.39E+03	9.46E+01	1.14E+01

Table 32

DOSE CALCULATION FOR INHALATION OF Pu-239 PARTICULATES PER BQ EXCRETED

Pu-239 Half Life - 8.78 E+06 Days Class - W
AMAD - 1 micron ALI - 2 E+02 Bq F_u = 5.4 E-01

Critical organ - bone surface
Committed Dose Equivalent (EQ) (Bone) = 2.5E-03 Sv/Bq
Wt. Committed Dose Equivalent (Eq) (Bone) = 7.4E-05 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction Of ALI Per Bq Excreted	Committed Dose Equiv. Bone (Sv/Bq Excreted)	Wtd.Committed Dose Equiv. Bone (Sv/Bq Excreted)
1.00E-00	3.05E-05		3.27E+04	1.63E+02	8.19E+01	2.42E+00
2.00E-00	6.46E-05		1.54E+04	7.73E+02	3.38E+01	1.14E+00
3.00E-00	9.69E-05		1.03E+04	5.15E+01	2.57E+01	7.63E-01
4.00E-00	1.28E-04		7.81E+03	3.90E+01	1.95E+01	5.78E-01
5.00E-00	1.57E-04		6.36E+03	3.18E+01	1.59E+01	4.71E-01
6.00E-00	1.85E-04		5.40E+03	2.70E+01	1.35E+01	4.00E-01
7.00E-00	2.11E-04		4.73E+03	2.36E+01	1.18E+01	3.50E-01
8.00E-00	2.36E-04		4.23E+03	2.11E+01	1.05E+01	3.13E-01
9.00E-00	2.60E-04		3.84E+03	1.92E+01	9.61E+00	2.84E-01
1.00E+00	2.83E-04	2.83E-04	3.53E+03	1.77E+01	8.83E+00	2.61E-01
2.00E+00		1.76E-04	5.68E+03	2.84E+01	1.42E+01	4.20E-01
3.00E+00		1.12E-04	8.93E+03	4.46E+01	2.23E+01	6.61E-01
4.00E+00		7.53E-05	1.33E+04	6.64E+01	3.33E+01	9.84E-01
5.00E+00		5.39E-05	1.85E+04	9.28E+01	4.65E+01	1.37E+00
6.00E+00		4.15E-05	2.41E+04	1.21E+02	6.03E+01	1.78E+00
7.00E+00		3.42E-05	2.92E+04	1.46E+02	7.30E+01	2.16E+00
8.00E+00		2.98E-05	3.36E+04	1.68E+02	8.40E+01	2.49E+00
9.00E+00		2.71E-05	3.69E+04	1.85E+02	9.23E+01	2.73E+00
1.00E+01		2.54E-05	3.94E+04	1.97E+02	9.85E+01	2.91E+00
2.00E+01		2.01E-05	4.98E+04	2.49E+02	1.25E+02	3.69E+00
3.00E+01		1.76E-05	5.68E+04	2.84E+02	1.42E+02	4.20E+00
4.00E+01		1.58E-05	6.33E+04	3.17E+02	1.58E+02	4.68E+00
5.00E+01		1.45E-05	6.90E+04	3.45E+02	1.73E+02	5.11E+00
6.00E+01		1.36E-05	7.35E+04	3.68E+02	1.84E+02	5.44E+00
7.00E+01		1.28E-05	7.81E+04	3.91E+02	1.95E+02	5.78E+00
8.00E+01		1.22E-05	8.02E+04	4.10E+02	2.01E+02	6.10E+00
9.00E+01		1.16E-05	8.62E+04	4.31E+02	2.16E+02	6.38E+00
1.00E+02		1.12E-05	8.93E+04	4.47E+02	2.23E+02	6.61E+00

Table 33

DOSE CALCULATION FOR INHALATION OF Pu-239 PARTICULATES PER Bq EXCRETED

Pu-239 Half Life - 2.20 E+04 Days Class - Y
AMAD - 1 micron ALI - 5 E+02 Bq F_u = 5.4 E-01

Critical organ - red marrow
Committed Dose Equivalent (EQ) (Red Marrow) = 7.6E-05 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Red Marrow) = 9.1E-06 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake In Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Bone (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Bone (Sv/Bq) Excreted)
1.00E-01	1.68E-06		5.91E+05	1.18E+03	4.49E+01	5.38E+00
2.00E-01	3.55E-06		2.81E+05	5.63E+02	2.14E+01	2.56E+00
3.00E-01	5.32E-06		1.87E+05	3.75E+02	1.42E+01	1.71E+00
4.00E-01	7.01E-06		1.42E+05	2.85E+02	1.08E+01	1.29E+00
5.00E-01	8.61E-06		1.16E+05	2.32E+02	8.82E+00	1.05E-00
6.00E-01	1.01E-05		9.90E+04	1.98E+02	7.52E+00	9.00E-01
7.00E-01	1.16E-05		8.62E+04	1.72E+02	6.55E+00	7.84E-01
8.00E-01	1.30E-05		7.69E+04	1.53E+02	5.84E+00	7.00E-01
9.00E-01	1.43E-05		6.99E+04	1.39E+02	5.31E+00	6.36E-01
1.00E+00	1.55E-05	1.55E-05	6.45E+04	1.29E+02	9.90E+00	5.87E-01
2.00E+00		9.64E-06	1.03E+05	2.07E+02	7.88E+00	9.43E-01
3.00E+00		6.09E-06	1.64E+05	3.28E+02	1.24E+01	1.49E+00
4.00E+00		4.05E-06	2.46E+05	4.93E+02	1.87E+01	2.29E+00
5.00E+00		2.87E-06	3.48E+05	6.96E+02	2.64E+01	3.17E+00
6.00E+00		2.18E-06	4.58E+05	9.17E+02	3.48E+01	4.17E+00
7.00E+00		1.78E-06	5.61E+05	1.12E+03	4.26E+01	5.11E+00
8.00E+00		1.53E-06	6.53E+05	1.30E+03	4.96E+01	5.94E+00
9.00E+00		1.38E-06	7.24E+05	1.44E+03	5.50E+01	6.59E+00
1.00E+01		1.29E-06	7.75E+05	1.55E+03	5.89E+01	7.05E+00
2.00E+01		1.00E-06	1.00E+06	2.00E+03	7.60E+01	9.10E+00
3.00E+01		8.81E-07	1.13E+06	2.27E+03	8.62E+01	1.03E+01
4.00E+01		8.04E-07	1.24E+06	2.48E+03	9.45E+01	1.13E+01
5.00E+01		7.57E-07	1.32E+06	2.64E+03	1.00E+02	1.20E+01
6.00E+01		7.28E-07	1.37E+06	2.74E+03	1.04E+02	1.25E+01
7.00E+01		7.12E-07	1.40E+06	2.80E+03	1.06E+02	1.27E+01
8.00E+01		7.03E-07	1.42E+06	2.84E+03	1.08E+02	1.29E+01
9.00E+01		6.99E-07	1.43E+06	2.86E+03	1.08E+02	1.30E+01
1.00E+01		6.99E-07	1.43E+06	2.86E+03	1.08E+02	1.30E+01

Table 34

DOSE CALCULATION FOR INHALATION OF Am-241 PARTICULATES PER Bq EXCRETED

Am-241 Half Life - 1.58 E+05 Days Class - W
AMAD - 1 micron ALI - 2.0 E+02 Bq Excretion Pathways Not Defined

Critical organ - bone surface
Committed Dose Equivalent (EQ) (Bone) = 2.5E-03 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Bone) = 7.6E-05 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Bone (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Bone (Sv/Bq) Excreted)
1.00E-01	1.49E-03		6.71E+02	3.35E-00	1.67E+00	5.10E-02
2.00E-01	2.84E-03		3.52E+02	1.76E-00	8.80E-01	2.67E-02
3.00E-01	3.87E-03		2.58E+02	1.29E-00	6.45E-01	1.96E-02
4.00E-01	4.65E-03		2.15E+02	1.07E-00	5.37E-01	1.63E-02
5.00E-01	5.25E-03		1.90E+02	9.52E-01	4.76E-01	1.44E-02
6.00E-01	5.70E-03		1.73E+02	8.68E-01	4.34E-01	1.31E-02
7.00E-01	6.04E-03		1.65E+02	8.27E-01	4.13E-01	1.25E-02
8.00E-01	6.30E-03		1.58E+02	7.93E-01	3.96E-01	1.20E-02
9.00E-01	6.50E-03		1.53E+02	7.69E-01	3.84E-01	1.16E-02
1.00E+00	6.66E-03	6.66E-03	1.50E+02	7.50E-01	3.75E-01	1.14E-02
2.00E+00		4.93E-04	2.02E+03	1.01E+01	5.07E+00	1.54E-02
3.00E+00		8.24E-05	1.21E+04	6.06E+01	3.03E+01	1.22E-01
4.00E+00		5.49E-05	1.82E+04	9.10E+01	4.55E+01	1.38E+00
5.00E+00		5.24E-05	1.90E+04	9.54E+01	4.77E+01	1.45E+00
6.00E+00		5.17E-05	1.93E+04	9.67E+01	4.83E+01	1.47E+00
7.00E+00		5.11E-05	1.95E+04	9.78E+01	4.89E+01	1.48E+00
8.00E+00		5.06E-05	1.97E+04	9.88E+01	4.94E+01	1.50E+00
9.00E+00		5.02E-05	1.99E+04	9.96E+01	4.98E+01	1.51E+00
1.00E+01		4.97E-05	2.01E+04	1.00E+02	5.03E+01	1.52E+00
2.00E+01		4.56E-05	2.19E+04	1.09E+02	5.48E+01	1.66E+00
3.00E+01		4.17E-05	2.39E+04	1.19E+02	5.99E+01	1.82E+00

Table 35

DOSE CALCULATION FOR INHALATION OF Am-242 PARTICULATES PER Bq EXCRETED

Am-242 Half Life - 6.68 E+01 Days Class - W
AMAD - 1 micron ALI - 3.0 E+06 Bq Excretion Pathways Not Defined

Critical organ - bone
Committed Dose Equivalent (EQ) (Bone) = 1.8E-07 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Bone) = 5.4E-09 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Bone (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Bone (Sv/Bq) Excreted)
1.00E-01	1.49E-03		6.71E+02	2.23E-04	1.20E-04	3.62E-06
2.00E-01	2.84E-03		3.52E+02	1.17E-04	6.33E-05	1.90E-06
3.00E-01	3.87E-03		2.58E+02	8.61E-05	4.65E-05	1.39E-06
4.00E-01	4.65E-03		2.15E+02	7.16E-05	3.87E-05	1.16E-06
5.00E-01	5.25E-03		1.90E+02	6.34E-05	3.42E-05	1.02E-06
6.00E-01	5.70E-03		1.75E+00	5.84E-05	3.15E-05	9.47E-07
7.00E-01	6.04E-03		1.65E+00	5.51E-05	2.98E-05	8.94E-07
8.00E-01	6.30E-03		1.58E+00	5.29E-05	2.85E-05	8.57E-07
9.00E-01	6.50E-03		1.53E+02	5.12E-05	2.76E-05	8.30E-07
1.00E+00	6.66E-03	6.66E-03	1.50E+03	5.00E-05	2.70E-05	8.10E-07
2.00E+00		4.93E-04	2.02E+03	6.76E-04	3.65E-04	1.09E-05
3.00E+00		8.24E-05	1.21E+04	4.04E-03	2.18E-03	6.55E-05
4.00E+00		5.49E-05	1.82E+04	6.07E-03	3.27E-03	9.83E-05
5.00E+00		5.24E-05	1.90E+04	6.36E-03	3.43E-03	1.03E-04
6.00E+00		5.17E-05	1.93E+04	6.44E-03	3.48E-03	1.04E-04
7.00E+00		5.11E-05	1.95E+04	6.52E-03	3.52E-03	1.05E-04
8.00E+00		5.06E-05	1.97E+04	6.58E-03	3.55E-03	1.06E-04
9.00E+00		5.02E-05	1.99E+04	6.64E-03	3.58E-03	1.07E-04
1.00E+01		4.97E-05	2.01E+04	6.70E-03	3.62E-03	1.08E-04
2.00E+01		4.56E-05	2.19E+04	7.30E-03	3.94E-03	1.18E-04
3.00E+01		4.17E-05	2.39E+04	7.99E-03	4.31E-03	1.29E-04

Table 36

DOSE CALCULATION FOR INHALATION OF Am-242m PARTICULATES PER Bq EXCRETED

Am-242m | Half Life - 5.55 E+04 Days | Class - W
AMAD - 1 micron | ALI - 2.0 E+02 Bq | Excretion Pathways Not Defined

Critical organ - bone surface
Committed Dose Equivalent (EQ) (Bone) = 2.5E-03 Sv/Bq
Wt. Committed Dose Equivalent (EQ) (Bone) = 7.6E-05 Sv/Bq

T Days	Fraction of Intake In Accumulated Urine	Fraction of Intake in Daily 24 Hr Urine Sample	Intake Per Bq Excreted	Fraction of ALI Per Bq Excreted	Committed Dose Equiv. Bone (Sv/Bq) Excreted)	Wtd.Committed Dose Equiv. Bone (Sv/Bq) Excreted)
1.00E-01	1.49E-03		6.71E+02	3.35E-00	1.67E+00	5.10E-02
2.00E-01	2.84E-03		3.52E+02	1.76E-00	8.80E-01	2.67E-02
3.00E-01	3.87E-03		2.58E+02	1.29E-00	6.45E-01	1.96E-02
4.00E-01	4.65E-03		2.15E+02	1.07E-00	5.37E-01	1.63E-02
5.00E-01	5.25E-03		1.90E+02	9.52E-01	4.76E-01	1.44E-02
6.00E-01	5.70E-03		1.73E+02	8.68E-01	4.34E-01	1.31E-02
7.00E-01	6.04E-03		1.65E+02	8.27E-01	4.13E-01	1.25E-02
8.00E-01	6.30E-03		1.58E+02	7.93E-01	3.96E-01	1.20E-02
9.00E-01	6.50E-03		1.53E+02	7.69E-01	3.84E-01	1.16E-02
1.00E+00	6.66E-03	6.66E-03	1.50E+02	7.50E-01	3.75E-01	1.14E-02
2.00E+00		4.93E-04	2.02E+03	1.01E+01	5.07E+00	1.54E-02
3.00E+00		8.24E-05	1.21E+04	6.06E+01	3.03E+01	1.22E-01
4.00E+00		5.49E-05	1.82E+04	9.10E+01	4.55E+01	1.38E+00
5.00E+00		5.24E-05	1.90E+04	9.54E+01	4.77E+01	1.45E+00
6.00E+00		5.17E-05	1.93E+04	9.67E+01	4.83E+01	1.47E+00
7.00E+00		5.11E-05	1.95E+04	9.78E+01	4.89E+01	1.48E+00
8.00E+00		5.06E-05	1.97E+04	9.88E+01	4.94E+01	1.50E+00
9.00E+00		5.02E-05	1.99E+04	9.96E+01	4.98E+01	1.51E+00
1.00E+01		4.97E-05	2.01E+04	1.00E+02	5.03E+01	1.52E+00
2.00E+01		4.56E-05	2.19E+04	1.09E+02	5.48E+01	1.66E+00
3.00E+01		4.17E-05	2.39E+04	1.19E+02	5.99E+01	1.82E+00

APPENDIX B

Computer Program

FLOW CHART